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Semiannual Report No. 3

on

PHOTOEMISSION SOLAR ENERGY CONVERTER

for the period

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Special Electron Devices Section
Electronic Tube Division
Westinghouse Electric Corporation
Baltimore 3, Maryland

Power Sources Division
Electron Components Research Department
U. S. Army Signal Research and Development Laboratory
Fort Monmouth, New Jersey

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SECTION I

PURPOSE

Since there is a considerable amount of solar energy flux in the vicinity of the earth's orbit, it would be desirable to have devices capable of converting this solar energy into electrical energy. This study is concerned with the feasibility of one such method of conversion employing the photoelectric effect and an experimental photogenerator made using available material and techniques. Since this photogenerator is expected to have useful efficiency and a high power-per-unit-weight, it will be particularly suited for space application.

This study has been divided into three major tasks: Task A, which deals with preliminary studies; Task B, which has as a goal a sealed-off glass photogenerator; and Task C, which has as a goal a sealed-off, thin-glass photogenerator.

SECTION II

ABSTRACT

The use of photoemission to convert solar photon flux into electrical power and the development of a high power-per-unit-weight photogenerator suitable for use in space, are considered in this study. Experimental results obtained with the movable-anode WX-3964 are presented and show how efficiency depends on anode-to-photocathode spacing. The results of the bell-jar and WX-4220 phototube experiments are given, showing the necessity of clean tube components and the desirability of a small volume during cesiation. A tentative design of a glass-tubing processing system is discussed and the design of the WX-4209 is given, showing the compatibility of the two. A schedule of work for the next year is given for both the WX-4209 photogenerator and the thin-glass photogenerator.

SECTION III

PUBLICATIONS, LECTURES, REPORTS, AND CONFERENCES

On 9 August 1960, a meeting was held between Mr. Stuart Shapiro. representing the Signal Corps, and Messrs. D. Callendar, A.S. Jensen, G.R. Kilgore, I. Limansky, representing Westinghouse. The progress of the contract and the work remaining was discussed, along with the possibility of continuing the contract.

On 22 September 1960, a meeting was held between Westinghouse Representatives and U. S. Army Signal Research and Development Laboratories personnel. Representing Westinghouse were Messrs. C. Arthur, D. Callendar, I. Limansky, and A.S. Jensen. Messrs. G. Hunrath, S. Shapiro, W. Schorr, H. Schwartz, and Dr. E. Kittl represented USASRDL while Muncie Crost represented Evans Signal Laboratories. Westinghouse gave an oral presentation which recapitulated the program made to date, analyzed the results obtained during the last year, and mapped out the program for next year.

SECTION IV

FACTUAL DATA

4.1 INTRODUCTION

The close spacing required in the photogenerator imposes stringent limitations with regard to the manner of processing this tube. If the spacing is to be a few mils thick for the tube in its final form, as the theoretical study indicates, a host of problems arise as to the sealing method, photosurface formation, etc. Even when the tube vacuum envelope is relatively thick, many of the same problems are encountered. This report describes the design of the tube under investigation, the problems met in its processing and construction, and how these problems were resolved.

During this period, the emphasis was placed on the bell-jar experiments and the WX-4220 photoemission control tubes. In addition, several WX-3964 photogenerators having movable anodes were made.

4.2 TASK A - PRELIMINARY STUDIES

4.2.1 Phase 2 - Electrode Processing

The general considerations involved in the preparation and processing of parts destined to comprise the photogenerator or the WX-4220 phototube have been covered in detail in the last two semiannual reports. This report covers both the application of these considerations in the making of photogenerator components, and the results.

4.2.1.1 Photocathode

Five glass photocathode substrates were prepared according to the procedure outlined in the second semiannual report. Copper and chromium evaporations were carried out within a Veeco four-inch bell-jar system capable of being pumped to a pressure of 2×10^{-7} mm Hg. Prior to these evaporations, the soda-lime glass substrate was outgassed by heating in a vacuum. Adhesion of the copper to the glass was improved over the adhesion obtained with no outgassing, and the 10-mesh-per-inch pattern was able to be etched into the deposited copper with no incident.

Manganese evaporation within the bell-jar upon the photocathode substrate was done using electrodeposited manganese upon an 8-mil tungsten wire. Some difficulty was experienced with brittle, frangible coatings until the evaporator was fired in vacuum to a temperature just below the point of evaporation before use.

Both manganese and antimony evaporations proceeded satisfactorily in the WX-4220 and bell-jar experiments. When cesium was admitted however, the expected photoemission did not develop, even when the photocathode substrate was heated to 150-170°C, the reaction range of the cesium antimonide. Reasons for this fault and ways to overcome it will be noted in a subsequent section.

4.2.1.2 WX-4220 Photoemission Control Tube

This tube is used to check on the photocathode processing during the course of this program. Its tentative construction was shown in Semiannual Report No. 1 and the present construction is shown in figure 1.

Of the ten WX-4220 tubes made during the period July-August 1960, all but two failed due to a leak which developed in the tip-off. The first two tubes had poor contact to the aluminized photocathode contact coating. However, subsequent tubes corrected for this by including three photocathode contact springs as shown in figure 1. Trouble was also experienced with the aluminium photocathode contact coating deposited in a vacuum system where no steps were taken to prevent the backstreaming of vacuum pump oil vapors during the aluminium evaporation. Bulbs prepared on this system were contaminated with the pump oil and had no measurable photoemission.

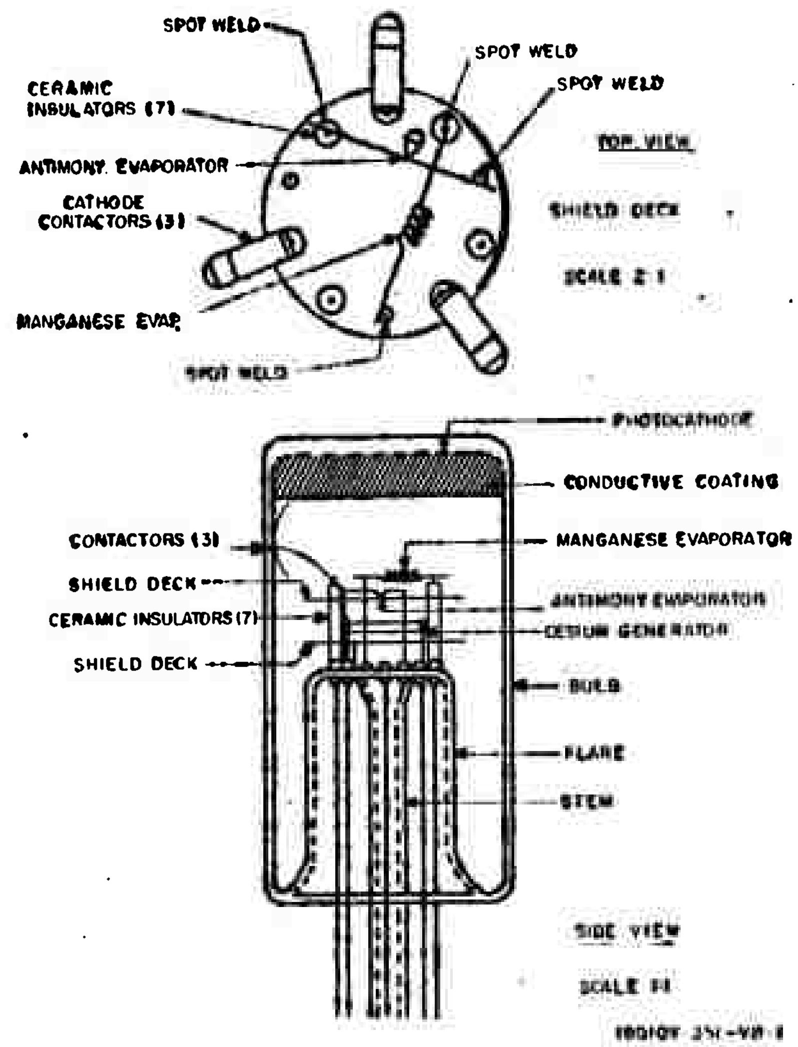


Figure 1. WX-4220 Photoemission Control Tube

In all cases, the performance of the tubes during processing were mediocre and the photoresponse during processing did not follow the normal course. During the formation of an acceptable photocathode, the photoresponse and leakage current decreases to a minimum as the cesium combines with the antimony to form cesium antimonide. Further processing (baking at 160° C) causes the photoresponse to increase to a maximum and the leakage current to fall to zero. In the case of the WX-4220 tubes made during this period, the photoresponse never increased past the minimum, no matter how long the tubes were baked. Table I is a chronology of a representative tube during processing.

TABLE I

CHRONOLOGY OF WX-4220, NO. 7

1. On System at 1100, 3 August 1960.

2. Bakeout:

Time	Temperature	Pressure in Manifold
1130	240° C	8×10^{-5} mm Hg.
1215	400	3×10^{-6} mm Hg.
1405	25	7×10^{-7} mm Hg.

3. Manganese Evaporation:

   7.5 amps at 7×10^{-7} mm Hg.
   light transmission measurement 100% → 80%

4. Manganese Oxidation

   150 microns with Power Supply set at 410 volt at 10 microamps (started with Tesla coil) light transmission measurement 88% → 96%

5. Antimony Evaporation

   4.5 amp at 7×10^{-7}
   light transmission measurement 100% → 70% first trial
   70% → 62% second trial

6. Cesium

   Oven at 150°C, cesium generator increased 1 amp per minute, 6.2 amps cesium involved. Maximum photocurrent during cesiation, 6 microamperes, mostly due to dark current. Photoresponse from 0.001 to 0.0017 microampere.

7. Tipped-off.

4.2.1.3 Anode

No change was made in the anode structure of the photogenerator. As noted in the second semiannual report, the anode consists of a woven stainless steel mesh, 100 mesh per inch, with silver electroplated on the side facing away from the photocathode and silicon monoxide vacuum deposited on the side facing the photocathode. The mesh is welded to an anode mesh support.

Preliminary tests indicate that the insulating coating does not perform its primary function of insulating the photocathode from the anode, since when the two are brought together a short circuit invariably occurs. Some additional work has been done with magnesium fluoride which was deposited on glass microscope slides for investigation. Some thought has been given to using a flat, etched copper mesh similiar to that previously used in the WX-3964. The structure of the WX-4209 has also been changed to permit the use of a welding ring, since contact may have been present between the ends of the mesh protruding in the direction of the photocathode.

4.2.1.4 Wide-Spaced Photogenerator - WX-3964

WX-3964 tubes were originally intended to be used to determine the effect of anode surface conditions upon the operation of the photogenerator. However it became quickly apparent that the design and processing of this tube was not sufficiently under control to separate the effect of the anode surface from the other variables influencing its operation. The basic design of the WX-3964 was changed therefore, to permit the anode mesh to be moved by a small amount relative to the photosurface (see figure 2). Also, the aluminized contact ring was extended so that the aperture of the photosurface was only 14.5 instead of 20 square centimeters. This was done to insure good contact between the photosurface and the aluminized contact ring.

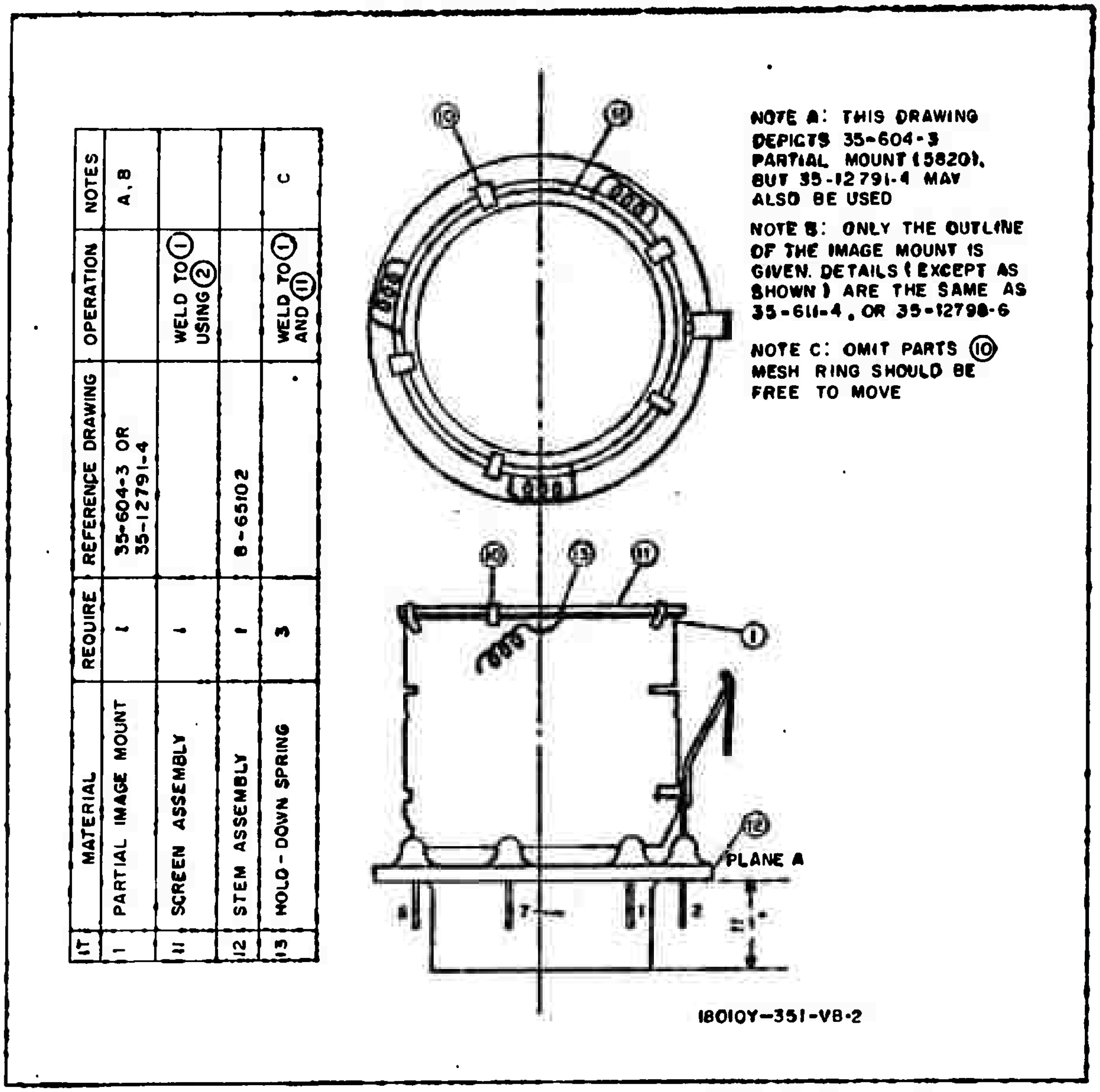


Figure 2. Complete Image Mount (Revision) of WX-3964 Wide-Spaced Photogenerator

The WX-3964 tubes were assembled at the Camera Tube Section and shipped to Baltimore for processing. The tubes were not prepumped at the Camera Tube Section nor filled with an inert atmosphere for shipping purposes. Of the nine tubes shipped to Baltimore, one failed during processing and four had poor tip-offs and went to air shortly after they were taken off the processing station. Data taken on five tubes may be seen in table 2. Table 2 also contains the experimental results obtained with the first group of six tubes which were assembled and processed at the Camera Tube Section for comparative purposes. Appendix A is included to show on-the-pump processing information on these tubes; reference to this section will show that of all the tubes processed, tube E-3 was the only one showing the proper photocurrent versus time relationship. Tube E-3 also had the highest microamperes per lumen response of all the WX-3964 tubes made. However, as a photogenerator it had less power output than tube E-5. Tube E-5 had silver-bismuth evaporated to a light transmission of 3 percent during on-the-pump processing; although its photoresponse was low (6 microamperes per lumen) as a photogenerator it had a higher efficiency (0.009 percent) than that of tube E-3 (0.001 percent). The same phenomenon was observed in tubes 4 and 5 made by the Camera Tube Section and reported in the second semiannual report. Table 2 shows that although the spacing between anode and photocathode for these tubes was essentially the same, the efficiency of tube 4 was three times as great as that for tube 5, even though the photoresponse of tube 4 was 1/4 that of tube 5. It seems that the thickness of the photosurface plays an important role in the photogenerator process.

The tubes processed at Special Electron Devices during this period were fabricated with movable anodes to make it possible to determine if there was any evidence of improvement in efficiency of power conversion due to a closer spacing of the anode and photocathode. Table 2 shows that there is a definite relationship between the distance separating the photocathode and anode and the efficiency of the photogenerator. Unfortunately, the separation could not be measured with any degree of accuracy, since the anodes were not fastened postively and could not be trusted to stay in a given position during a series of measurements involving excessive handling.

TABLE 2
REPRESENTATIVE TUBE DATA

TUBE NO.	PHOTORESPONSE (μa/lumen 90V, 3104, K)	POWER (microwatts)	LOAD RESISTANCE (k-ohms)	SPACING (mils)	PHOTOCATHODE AREA (cm^2)	EFFICIENCY (percent)
1	13	2.2	70	108	23.8	0.0001
2	3	40	1.6	89	20.5	0.0033
3	3	29	1.5	109	20.5	0.0024
4	10	130	1.0	69	21.2	0.010
5	39	4.4	16	73	23.8	0.003
6	13	0		92	24.6	0
Above Tubes Processed at Camera Tube Division						
E-2	Poor Tipoff	5.5	10	Minimum	14.5	0.00063
		5.0	18	Maximum		0.00058
E-3	25	11.0	6	Minimum	14.5	0.0013
		9.0	6	Maximum		0.0010
E-5	6	70	1.0	Minimum	14.5	0.0090
		38	2.0	Maximum		0.0044
E-6	2	23	2.7	Minimum	14.5	0.0016
		15	4.0	Maximum		0.0017
E-8	3	12	4.0	---	14.5	0.0014
Above Tubes Processed at Special Electron Devices						

Note that a value of photoresponse (i. e., microamperes per lumen) is given as part of the data in table 2. It is important to record this value, although it does not have direct bearing on photogenerator output, since it compares the quality of the photosurfaces made in this laboratory with photosurfaces made throughout the industry. Since a lumen is a unit of visible light power, it may be possible to extract valuable power conversion data from this measurement. However, there is no general relationship between the radiant energy and the luminous flux emitted by a light source. Therefore, the best relationship that can be made is to define the luminous flux as the least mechanical equivalent of light (5560 Å). Nevertheless, this reading is still valuable in monitoring the quality of the photocathodes made in this laboratory and comparing them against those made in other laboratories.

To this end, a photocell testing station was constructed to give a solid angle subtending a light flux of 1 lumen (Appendix B). The photoresponse measurements of table 2 were obtained with the use of this station, and the results obtained earlier at the Camera Tube Section for tubes 1 through 6 were checked and found to be within experimental error. However, before this test set is considered an acceptable standard, it will be necessary to recalibrate the test lamp at a color temperature of 2870°K, the accepted value for a light source to give the absolute luminous sensitivity of a photodiode. The photocell test lamp employed in the photoresponse measurements given in this report was operated at rated voltage (10.7 volts) which gave a higher color temperature (3104°K) than required.

For future measurements of spectral sensitivity of the photoemissive coatings, Osram Spectral lamps have been ordered: one mercury lamp with a window to extend the range in the ultraviolet to 230 millimicrons and one sodium lamp. Also, Bausch and Lomb second-order interference filters which pass the 436, 546, and 589 millimicron lines with 8 millimicron half-width have been ordered.

4. 2. 2 Phase 3 - Bell-Jar Processing System

The primary goal of the bell-jar processing equipment is the evaporation of a photosurface upon the photocathode substrate, and a low work-function surface upon the anode. Since the two are in close proximity in a finished photogenerator, it is necessary to have a method of moving them relative to each other after evaporation of the base metals. In addition, the processing system should be versatile and easy to clean. Also, an electrical measuring system should be included to determine the percent light-transmission through the photocathode substrate, photoelectric response, and the degree of vacuum in the system.

4. 2. 2. 1 Mechanical Arrangement

The evaporation can design was changed from an enclosed, unheated glass cylinder to a semienclosed heated glass cylinder (see figure 3). It was hoped that heating the photosurface glass substrate would accelerate the rate of reaction between the cesium and antimony, but the results proved disappointing. Cold cesiation (using an enclosed, unheated glass cesiation can) appeared to give a large initial photoemission which subsequently decayed to a negligible amount within an hour. Hot cesiation within a semienclosed glass cesiation can did not improve the situation, i. e., the photoemission did not have the large initial surge and the photocurrent still decayed to a negligible amount within an hour.

No other changes in the mechanical arrangement as described in the last semiannual report were made, and emphasis was placed on obtaining as much information as possible from the bell-jar processing station before proceeding to the glass-tubing vacuum system mentioned in the second semiannual report.

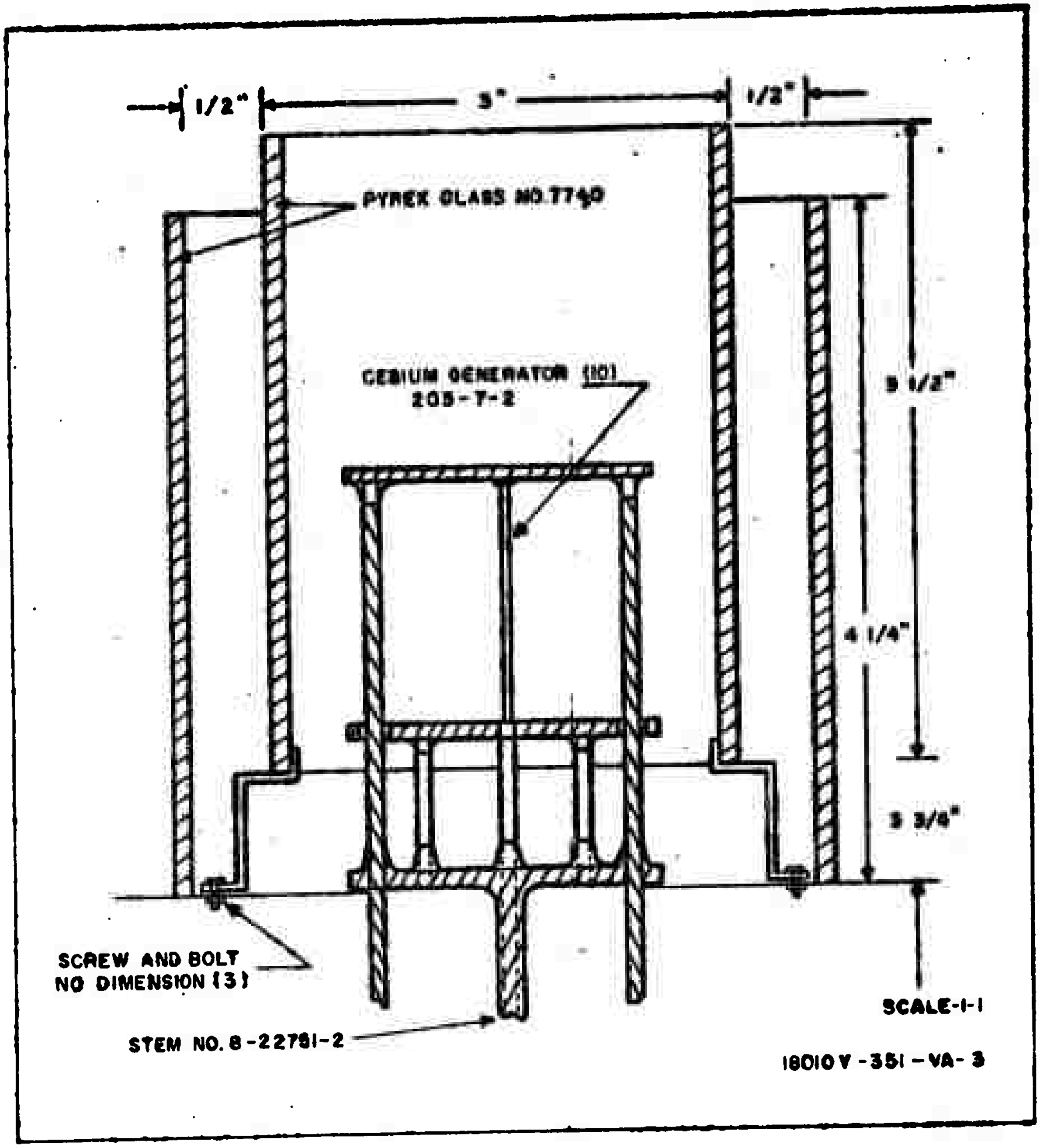


Figure 3. Cesiation Can and Evaporator Assembly

4.2.2.2 **Electrical Arrangement**

Figure 4 is a schematic diagram of the photoemission-photogenerator measurement circuit included in the processing station. This circuit will provide a quick test connection to the photogenerator under test for either a photoemission test, or to determine the amount of power output from the tube as a photogenerator. The information (voltage across R_3 or R_4) is presented upon the Weston Strip Chart Recorder through the automatic readout chassis described in the second semiannual report. Resistors R_3 and R_4 are usually fixed as noted in figure 4, but may be varied if more extensive tests are required.

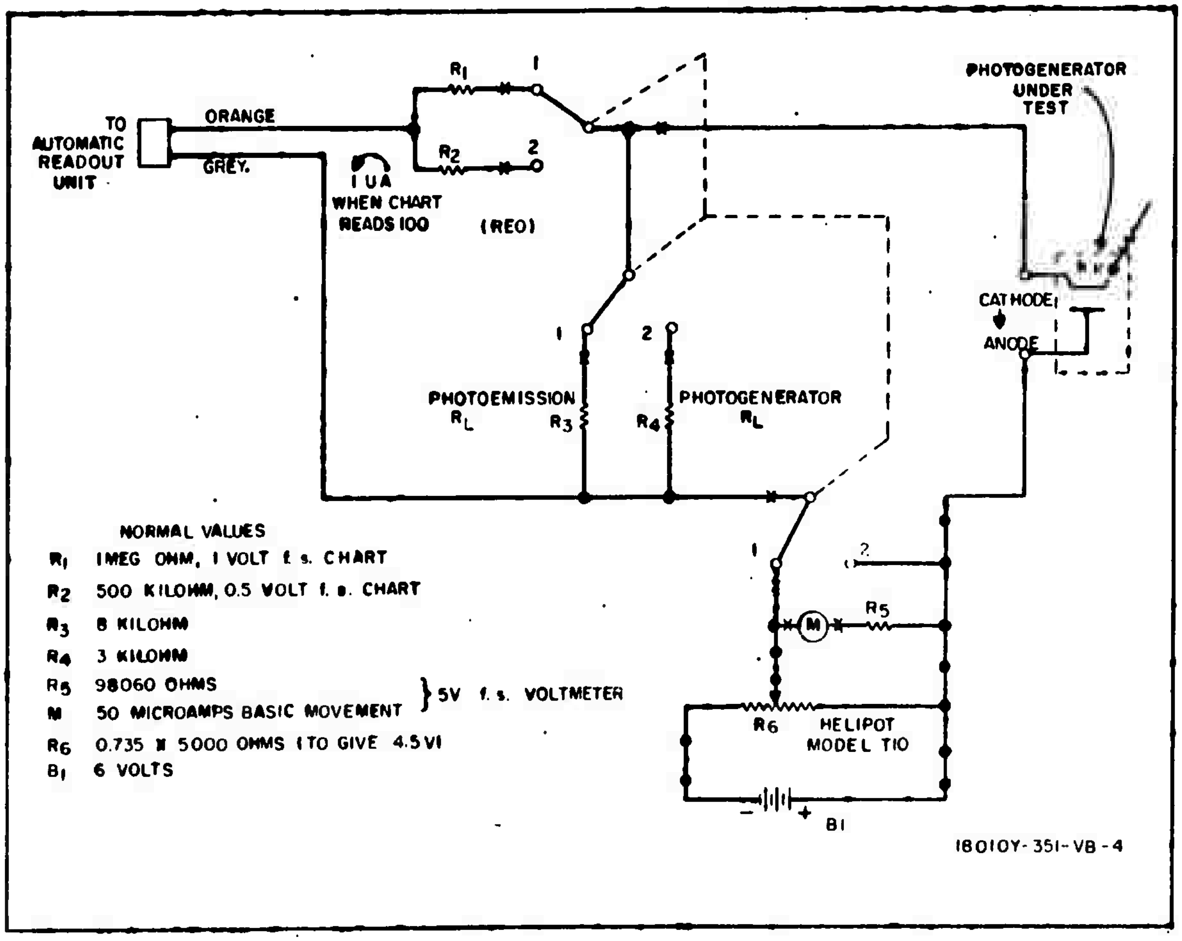


Figure 4. Schematic Diagram of Photoemission-Photogenerator Measurement Circuit

4.3 TASK B - SEALED-OFF GLASS PHOTOGENERATOR

The aim of this task is to construct a thin, photoemissive power converter (Phase 2). As an intermediate step, the photogenerator is processed in a demountable vacuum system (Phase 1) to determine its characteristics as a function of the anode-to-cathode spacing, anode surface, and other parameters.

4.3.1 Phase 1 - Bell-Jar Experiment

Three additional bell-jar experiments were conducted but none produced useful data with respect to the characteristics of the photogenerator. The pumping schedule outlined in the second semiannual report was used with minor variations (i. e., greater amount of cesium, cesiation can heated). No difficulty was experienced with evaporation of the base metals, antimony and manganese. However, cesiation did not produce the desired effects. Consequently, it must be concluded that in every case cesiation was incomplete. While there was definite evidence of photoemission, the magnitude was so small that true space charge conditions could not be established to test the photogenerator concept. This test requires that a sufficient number of photoelectrons is emitted to constitute a space charge somewhere between the photocathode and a movable anode. By moving the anode relative to the photocathode by known increments and measuring the efficiency of the photogenerator, it should be possible to find the optimum anode-to-cathode spacing for maximum efficiency.

Experience with the bell-jar processing system showed that a number of factors contributed to incomplete cesiation. In spite of the care taken to minimize the number of components used in the vacuum system, the number was still considerable and each component was a source of gas during cesiation. Also, the volume of the bell-jar was too large to permit sufficient cesium pressure to be built up to allow the formation of cesium antimonide, particularly if a portion of the cesium was removed as a result of gettering the occluded gases within the bell-jar walls.

The zeolite trap, although successfully used for the reduction of oil-backstreaming, could not be isolated from the bell-jar during its degassing cycle and was a possible contributor of gas. The zeolite can be expected to have a high affinity for cesium and may actually act as a cesium getter.

Deficiencies with the photocathode substrate transport mechanism (see figure 5) were also noted. To have close spacing and parallelism between the photocathode and anode, the mechanical tolerances of the transporting device had to be closely held. However, this was not practical due to the amount of play in the rotary motion device. Because of the cantilever construction of the transporting device, it would not be possible to apply adequate pressure to make the indium cold seal during the final sealing step of the processing.

In general, the bell-jar approach had certain inherent disadvantages which could not be overcome within a reasonable amount of time, and which were not immediately apparent at the start of the investigation.

4.3.2 Phase 2 - Sealed-Off Glass Photogenerator

Most of the work during this period was performed on the WX-4220, the WX-3964, and the bell-jar experiments. Little work was done with the WX-4209. Five sets of parts were readied for sealing experiments with the WX-4209 and an anode support and mesh assembly were used as the anode in the last two bell-jar experiments; however, no active attempts to assemble the anode and glass backing plate were made.

In preparation for the work of the next period, several changes were made in the design of the WX-4209. The aperture of the photocathode was reduced to 2-5/8 inches and the anode design was changed to permit the use of an anode mesh support ring (see Appendix C). This ring will permit the anode mesh to be welded to the anode mesh support as shown, and will prevent the stray ends of the mesh from contacting the photocathode. The material of the anode is to be Sylvania Alloy No. 4 or an equivalent metal (Driver Harris No. 14; Carpenter No. 426) having the coefficient of expansion of soda-lime glass (92×10^{-7} cm/cm/°C).

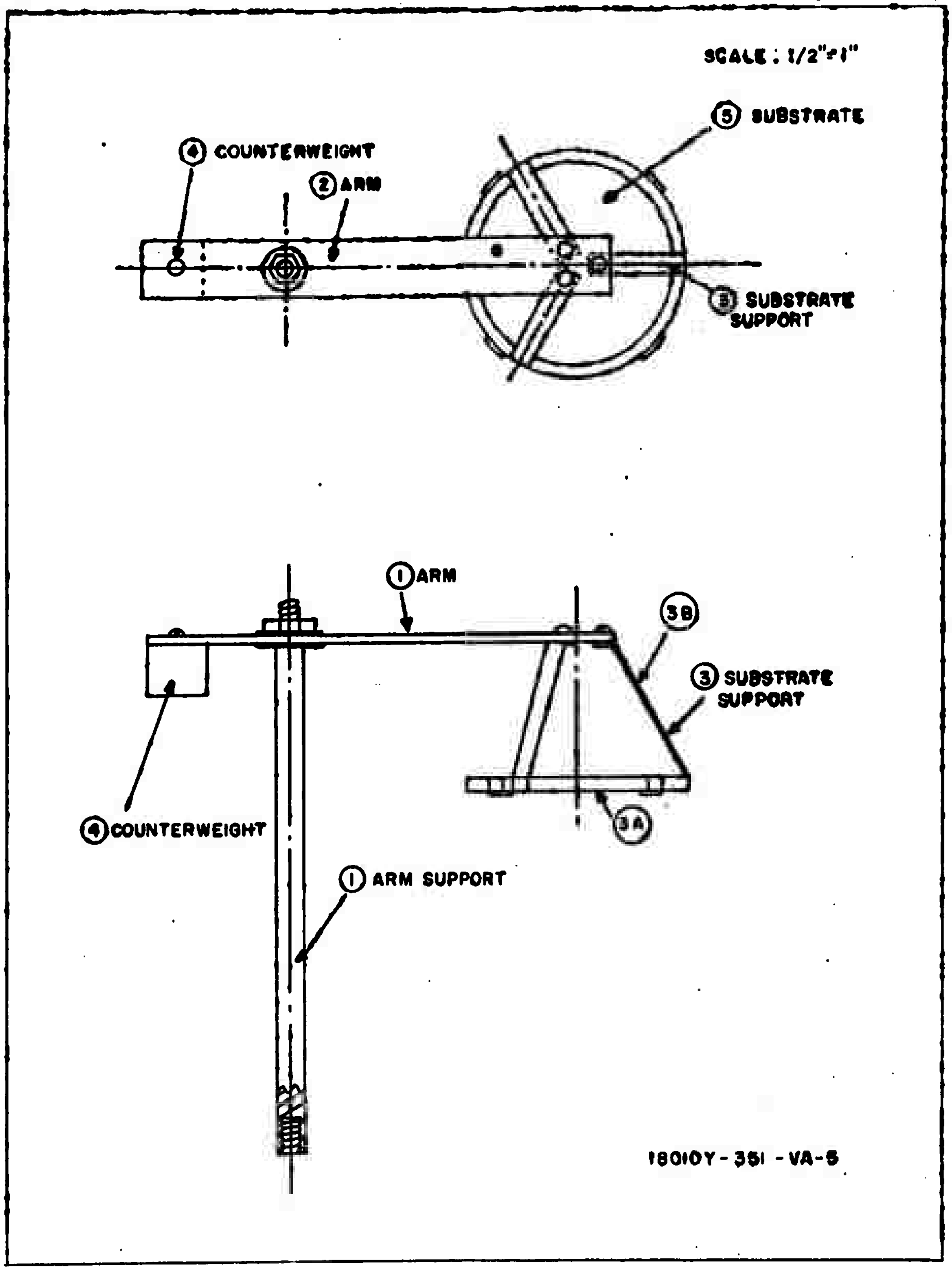


Figure 5. Transport Device Attachment for Use in Kinney Station

SECTION V

CONCLUSIONS

It was found that the bell-jar processing station was not the ideal configuration within which to make photogenerators. Its limited accessibility, large volume, and unwieldiness were noted during the course of the bell-jar experiments, and it was observed that full cesiation of the photosensitive surface was never effected. Work with the WX-4220 showed that cleanliness was of greater importance than heretofore believed. Even though the photoresponse of a given WX-4220 was high at some time during its processing, the photoresponse invariably was low upon tip-off, indicating incomplete formation of cesium antimonide. Normally, cesium antimonide is a stable compound at room temperature and only the presence of contaminants will cause it to disappear. Finally, the evidence of the WX-3964 tubes assembled in the Camera Tube Section, and successfully processed at Baltimore, points out the importance of adequate processing prior to on-the-pump processing, and shows that the pumping schedule and pumping equipment for the WX-4220 was reasonable for this purpose, since these tubes showed comparable photoresponses to those pumped in the Camera Tube Section.

The main difference between the WX-4220 and WX-3964 tubes was the extensive cleaning and firing done on the WX-3964 parts at the Camera Tube Section, as compared with only chemical cleaning done at the Baltimore Laboratories. Evidently, chemical cleaning is not sufficient processing for phototubes and it is necessary to further degas the components parts. Provisions are being made to vacuum fire the WX-4220 metal and ceramic parts before assembly within the tube.

The same precautions apply to the parts within the bell-jar processing station. Due to the large physical size of some of the components contained within the bell-jar, it was not possible to vacuum fire them using the equipment on hand at that time. Some outgassing was done during the course of the processing by virtue of the heat radiated by the zeolite trap and substrate heater contained within the bell-jar, but it was insufficient to cause complete degassing. In particular, the bell-jar could not be heated to a suitable temperature due to the danger of implosion: all these factors contributed to the large volume of contaminating gases suspected to be within the system. Also, when the zeolite trap was being outgassed, the evolved gases would be discharged into the bell-jar, since there was no way to isolate the trap from the bell-jar.

Therefore, in addition to the objections given to the bell-jar processing system in the second semiannual report, experience with the WX-4220, WX-3964, and the bell-jar experiments, added substance to the belief that a radical change was necessary in the processing system. This change was tentatively outlined in the second semiannual report and is shown schematically in figure 6, and to scale in figure 7. The aspect of the glass cross has been changed from the one shown in the second semiannual report, to one that avoids a cantilever arrangement for the anode assembly transport structure. Figure 8 is a sketch of the anode support structure and may be seen to have provisions for attaching an ULTEK gettering pump and a cesium generator. The latter would be of the normally stable cesium chromate-silicon mixture, placed in a nickel tube, and capable of being heated by RF energy.

Figure 9 shows the photocathode substrate support structure, including the antimony and manganese metal evaporators. Reference to figures 8 and 9 will show that when the stainless steel constriction and anode support plate are in a horizontal line, the volume between the photocathode substrate and the anode is closed off from the rest of the system. In this position, it is also possible to operate the ULTEK gettering pump by

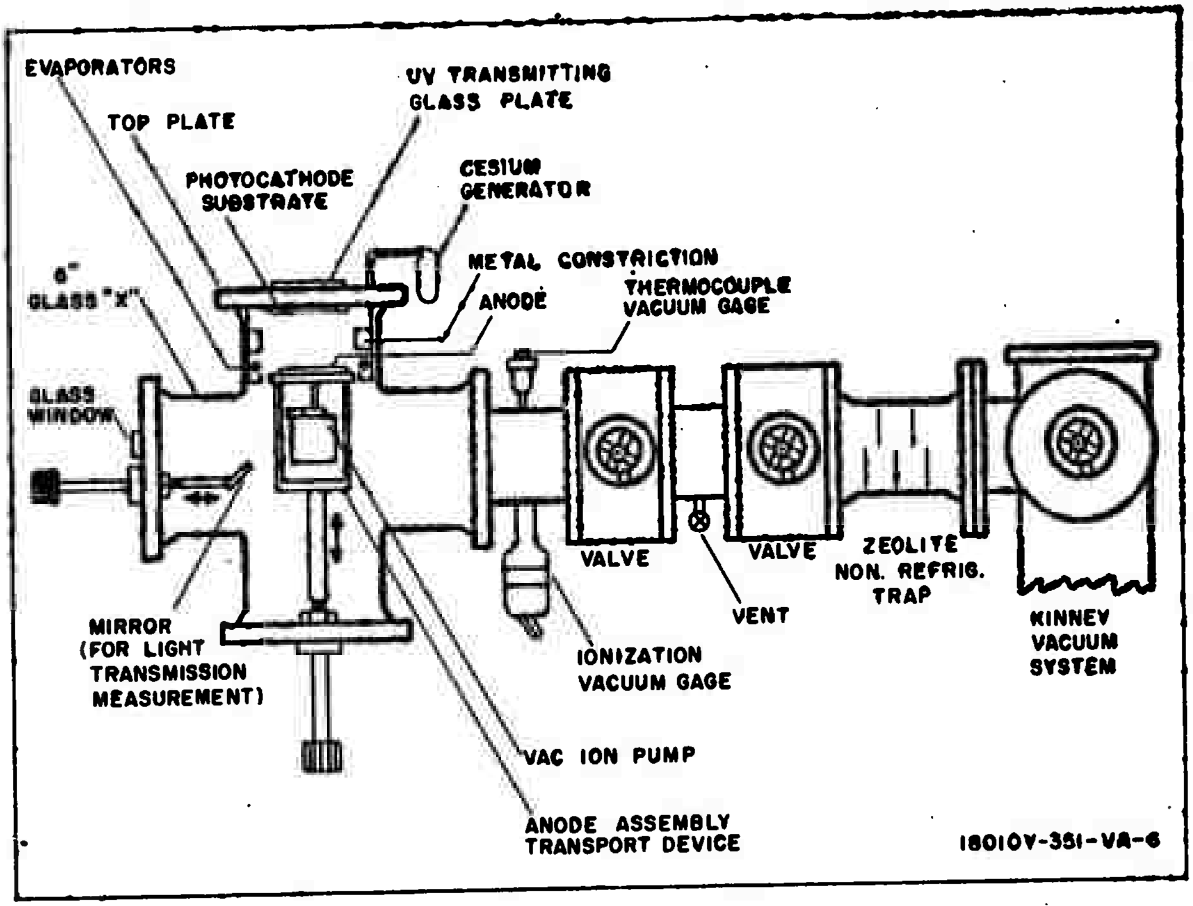


Figure 6. Glass Tubing Vacuum System

connecting a high voltage to the pump through an extensible connector passing through the bottom plate holding the anode assembly transport device. During the sealing of the anode and cathode, this pump will be useful in determining the quality of the seal, since it is also a vacuum indicator. During the sealing procedure, a small amount of rare gas can be introduced into the system, and leakage of this gas through the photocathode-anode seal can be detected by the pump. In particular, this arrangement permits the cesium to be released within a small volume so that sufficient pressure may be built up within this volume to allow the cesium antimonide reaction to go to completion.

One of the objectives of the first year of investigation was the determination of the efficiency of the photogenerator as a function of the distance between the photocathode and anode. Due to the difficulties with the bell-jar

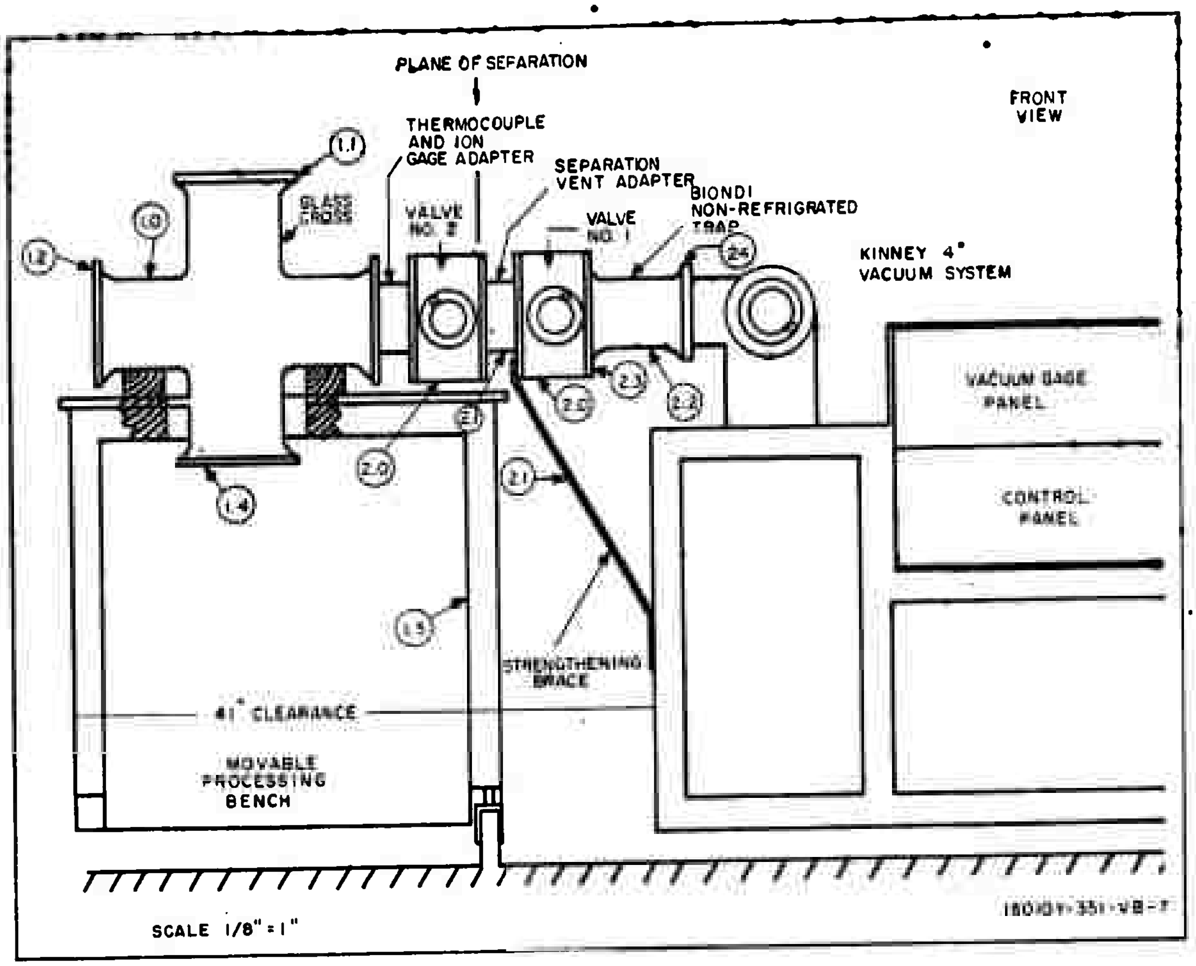


Figure 7. Photogenerator Processing System

processing system, it was not possible to gather significant data as originally planned, although experiments with the WX-3964 showed that there was a definite relation between the photocathode-anode spacing and efficiency. Figure 10 is a drawing of the processing system shown in figure 7, but being pumped by a 5-liter-per-second VacIon pump, and capable of being moved outdoors for measurement of photogenerator characteristics under actual operating conditions. It should be noted that at the same time, the Kinney Vacuum Station can be time shared for the processing of WX-4220 tubes, as shown in figure 11. In all cases, the Biondi Non-Refrigerated trap can be outgassed without exposing the contents of the processing system to the evolved gases, since valve No. 1 can be shut. Also, the Biondi trap does not have to go to air each time the processing system is converted

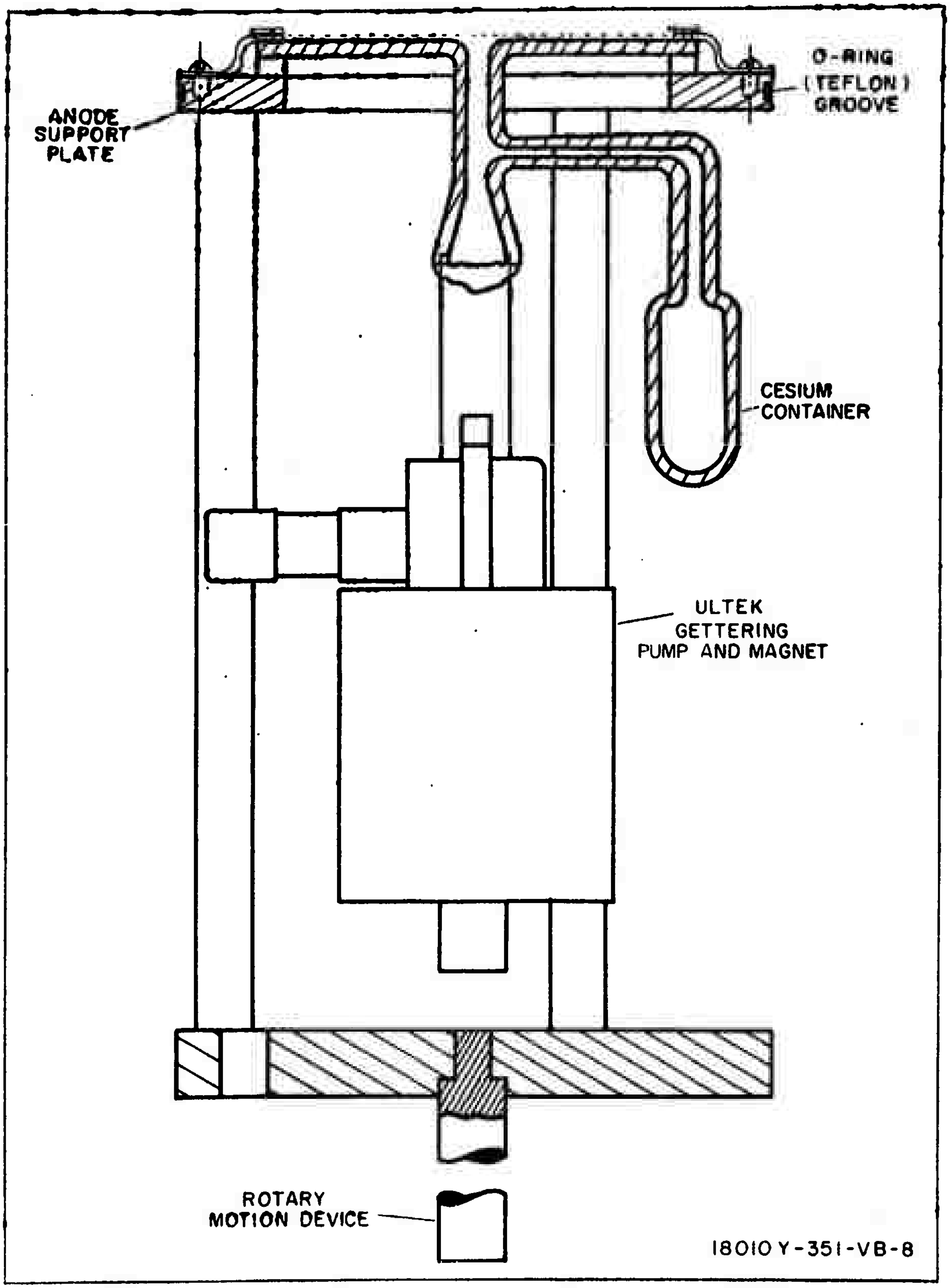


Figure 8. Anode Support Structure

for either WX-4209 or WX-4220 processing. When the Kinney system is not used for processing, it can be kept in operation thereby maintaining the Biondi trap in a condition of continual readiness. This was not possible with the bell-jar system, and it was necessary to go through a long (one day) degassing period prior to processing. All in all, the proposed design is expected to resolve the problems experienced with the bell-jar processing system, and provide a versatile processing setup for all phases of the photogenerator program.

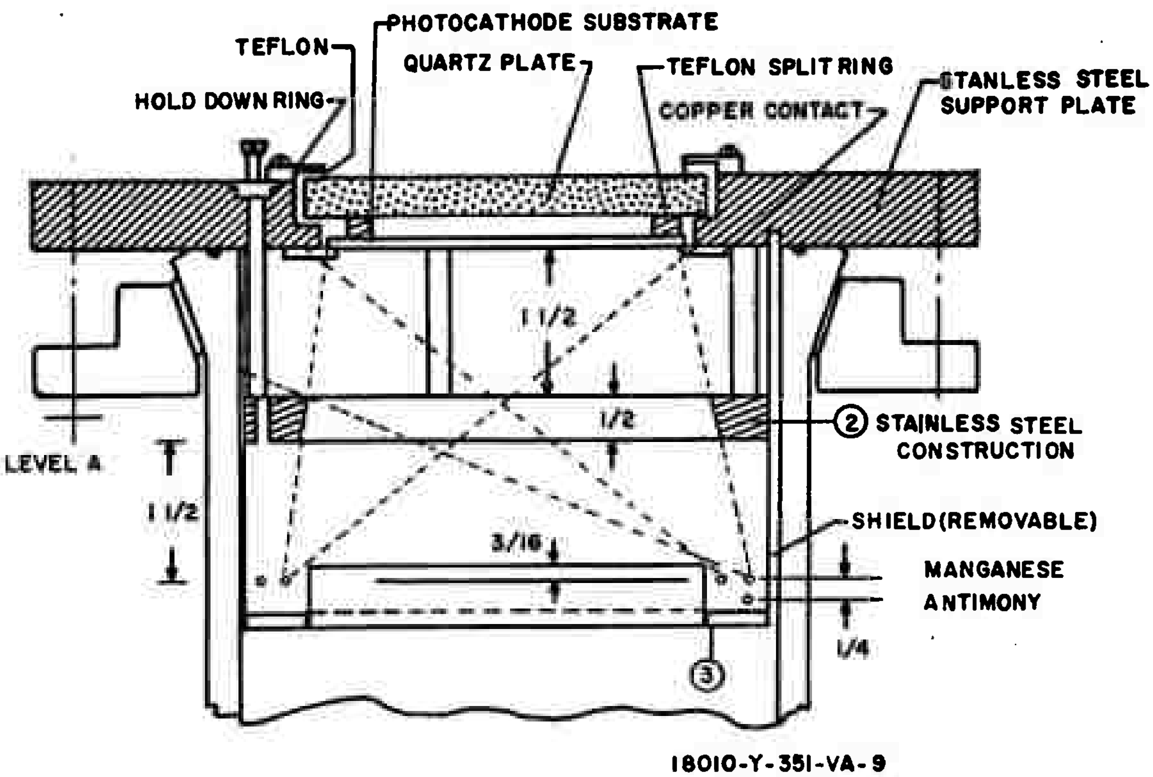


Figure 9. Photocathode Substrate Support

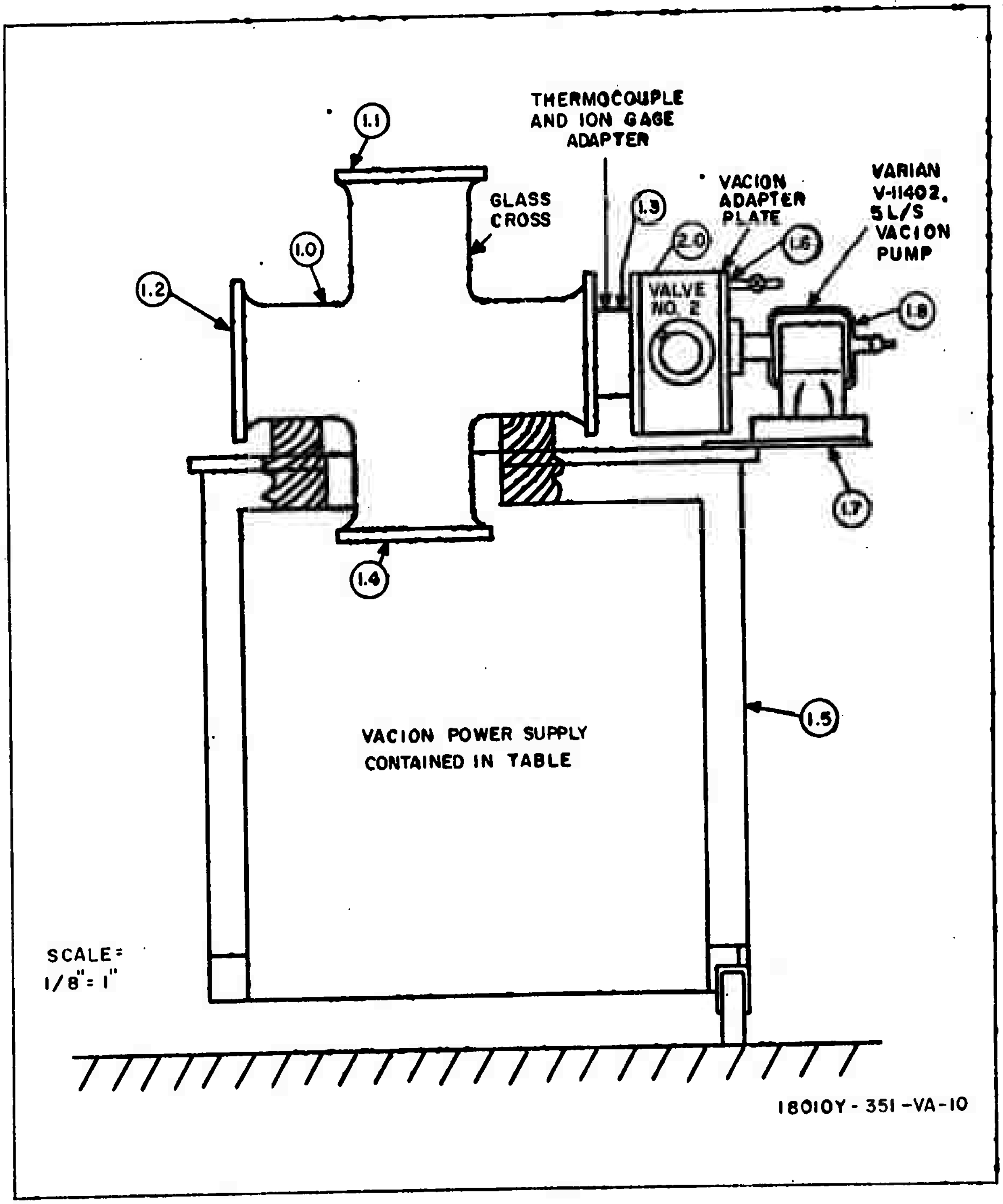


Figure 10. Movable Processing Bench

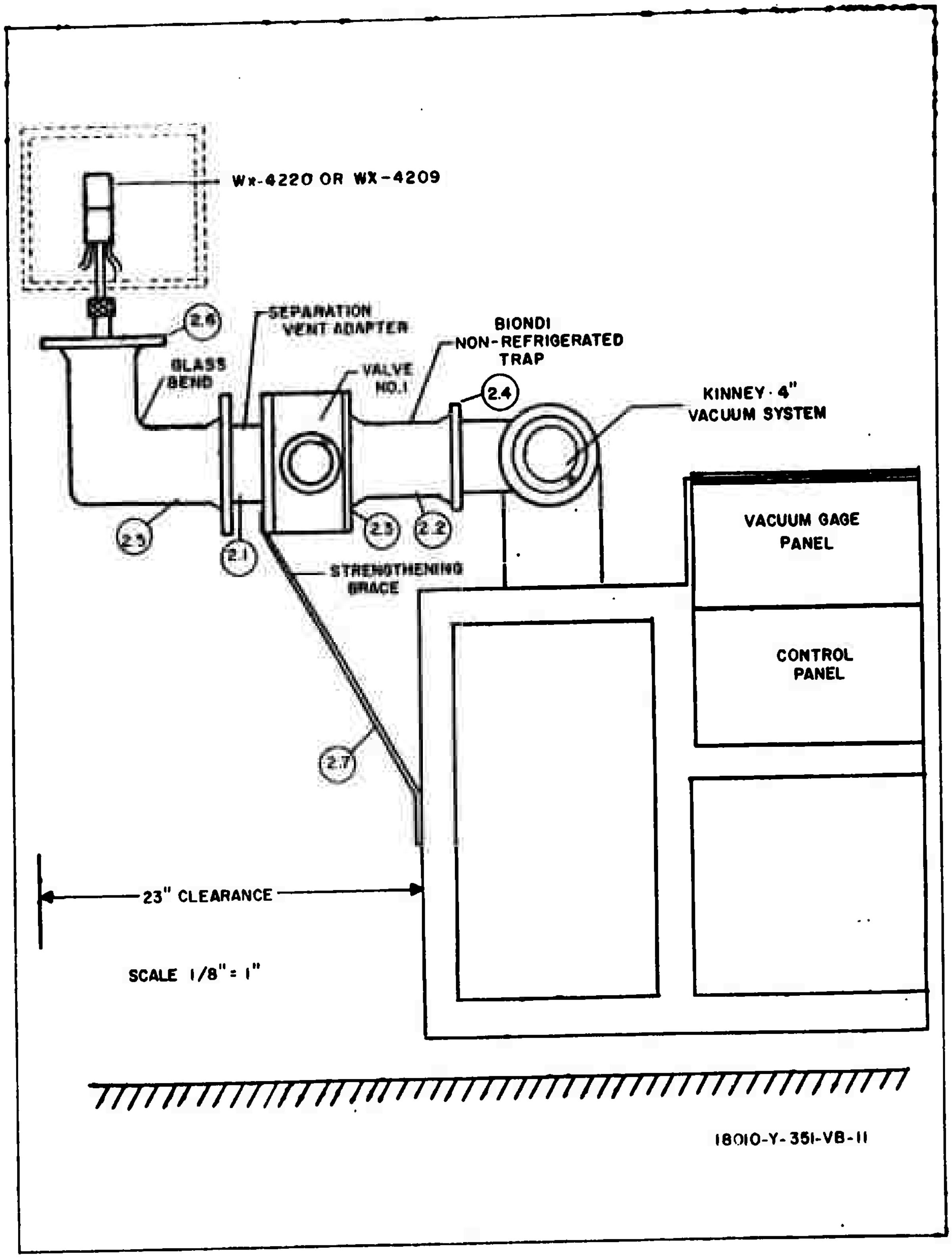


Figure 11. Kinney Station (Revised)

SECTION VI

PROGRAM FOR NEXT INTERVAL

6.1 GENERAL

Based upon the investigations performed during the past year, the effort during the next interval will be aimed in three main directions:

a. The glass tubing processing system construction and utilization;

b. Construction and processing of WX-4220 photoemissive control tubes;

c. Construction and sealing technique of the WX-4209 photoemissive solar power converter.

In addition, several subsidiary programs will be undertaken, some of which will be extensions of work started during the last period, while others will be generated by results obtained during this reporting period.

To conform to the statement of work on the "Proposal for Photoemissive Solar Power Converter" dated 16 September 1960, the Task-Phase notation will be changed as follows:

Task A - Preliminary Studies

Phase 1 - Electrode Surface Studies

Phase 2 - Glass Tubing Processing System

Phase 3 - WX-4220 Photoemission Control Tube

Phase 4 - Measurement Techniques

Task B - WX-4209 Thick-Glass Photogenerator

Phase 1 - WX-4209 Vacuum Sealing Methods

Phase 2 - WX-4209 Glass-Sandwich Photogenerator (Demountable)

Phase 3 - WX-4209 Glass-Sandwich Photogenerator (Sealed-Off)

Task C - Thin-Glass Photogenerator

Phase 1 - Thin-Glass Vacuum Sealing Methods

Phase 2 - Thin-Glass Sandwich Photogenerator (Demountable)

Phase 3 - Thin-Glass Sandwich Photogenerator (Sealed-Off)

The following areas will be concentrated upon during the next period:

a. Task A, Phase 2 - Glass Tubing Processing System;

b. Task A, Phase 3 - WX-4220 Photoemission Control Tubes;

c. Task B, Phase 1 - WX-4209 Vacuum Sealing Methods.

6.2 TASK A, PHASE 2 - GLASS TUBING PROCESSING SYSTEM

A brief description of the glass tubing processing system and the reason for its necessity is covered in Section V. The component parts will be made and tested on the vacuum system. A partial list of the problems that are expected during the construction and shakedown are as follows:

a. Outgassing of the components;

b. Design of evaporators;

c. Heating of components during cesiation;

d. Measurement of temperature;

e. Mechanical alignment of anode and photocathode;

f. Procedure and configuration for sealing under vacuum (together with Task B, Phase 1);

g. Feasibility of operating processing system with 5 liter per second VacIon Pump.

During the testing of the processing system, parts made for the WX-4209 will be used since this will be the photogenerator configuration that will be made during this period.

6.3 TASK A, PHASE 3 - WX-4220 PHOTOEMISSION CONTROL TUBE

The work upon this tube will take place coincidentally with work done with the glass tube processing system, since the results will be directly applicable. The processing of this tube will be altered to include vacuum firing of parts prior to use, and the magnitude of the photoemission current will be used as before to gage the degree of cleanliness required in the processing system.

6.4 TASK B, PHASE 1 - WX-4209 - VACUUM SEALING METHODS

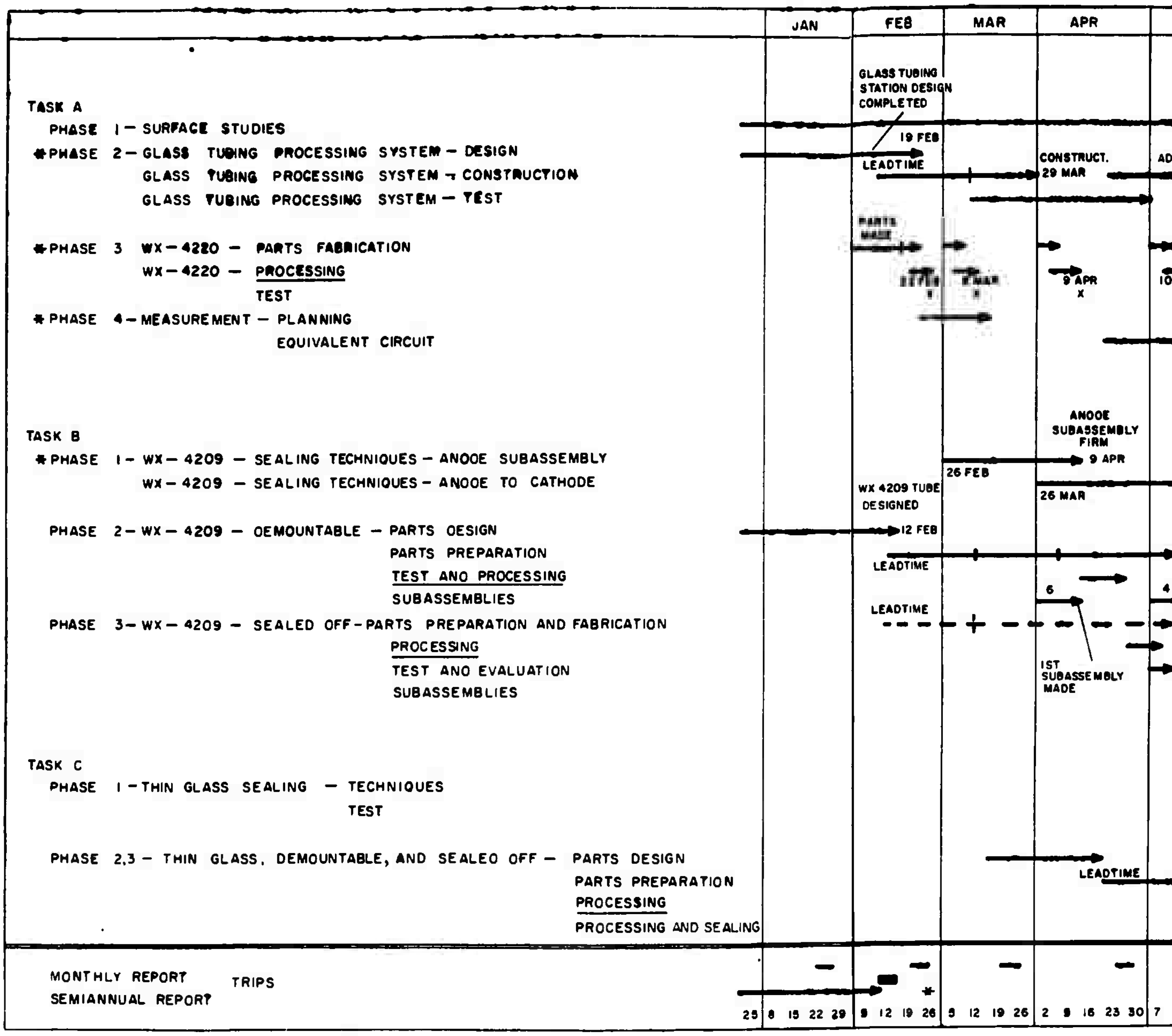
The work will concentrate upon sealing the glass and metal parts of the anode subassembly, since this subassembly is required for both the sealed-off and demountable versions of the WX-4209. At the same time, work will be started upon sealing the photocathode to the anode. This will be done first in air, then on dummy tubes within the processing system in an effort to determine a sealing method compatible with the method of processing.

6.5 OTHER WORK TO BE PERFORMED

Task A, Phase 4 (Measurement Techniques) will be continued. This phase will be concerned not only with electrical measurements of efficiency of the photogenerator, but also the determination of the equivalent circuit of this device, its spectral sensitivity, and the design of experiments required to prove the photogenerator concept or to optimize its efficiency. It is expected that this will also pave the way for an assessment of the effect of the electrode surface (Task A, Phase 1).

6.6 SCHEDULE OF WORK

A schedule for the next two periods is given in figure 12, showing the comparative time occurrence of the various phases of the program given in Task-Phase Notation. Although it is difficult to predict what the outcome of various investigations will be and base a firm schedule upon this prediction, the well-defined program set forth in figure 12 will permit the use of this schedule as a series of reasonable goals.


JAN
FEB
MAR
APR
TASK A
PHASE I — SURFACE STUDIES
*PHASE 2 — GLASS TUBING PROCESSING SYSTEM — DESIGN
GLASS TUBING PROCESSING SYSTEM — CONSTRUCTION
GLASS TUBING PROCESSING SYSTEM — TEST
*PHASE 3 WX — 4220 — PARTS FABRICATION
WX — 4220 — PROCESSING
TEST
*PHASE 4 — MEASUREMENT — PLANNING
EQUIVALENT CIRCUIT
TASK B
*PHASE I — WX — 4209 — SEALING TECHNIQUES — ANODE SUBASSEMBLY
WX — 4209 — SEALING TECHNIQUES — ANODE TO CATHODE
PHASE 2 — WX — 4209 — DEMOUNTABLE — PARTS DESIGN
PARTS PREPARATION
TEST AND PROCESSING
SUBASSEMBLIES
PHASE 3 — WX — 4209 — SEALED OFF — PARTS PREPARATION AND FABRICATION
PROCESSING
TEST AND EVALUATION
SUBASSEMBLIES
TASK C
PHASE I — THIN GLASS SEALING — TECHNIQUES
TEST
PHASE 2,3 — THIN GLASS, DEMOUNTABLE, AND SEALED OFF — PARTS DESIGN
PARTS PREPARATION
PROCESSING
PROCESSING AND SEALING
MONTHLY REPORT
SEMIANNUAL REPORT
TRIPS
GLASS TUBING STATION DESIGN COMPLETED
19 FEB
LEADTIME
CONSTRUCT.
29 MAR
PARTS MADE
9 APR
ANODE SUBASSEMBLY FIRM
9 APR
26 FEB
WX 4209 TUBE DESIGNED
26 MAR
12 FEB
LEADTIME
LEADTIME
6
IST SUBASSEMBLY MADE
LEADTIME
25 8 15 22 29 5 12 19 26 5 12 19 26 2 9 16 23 30 7

1

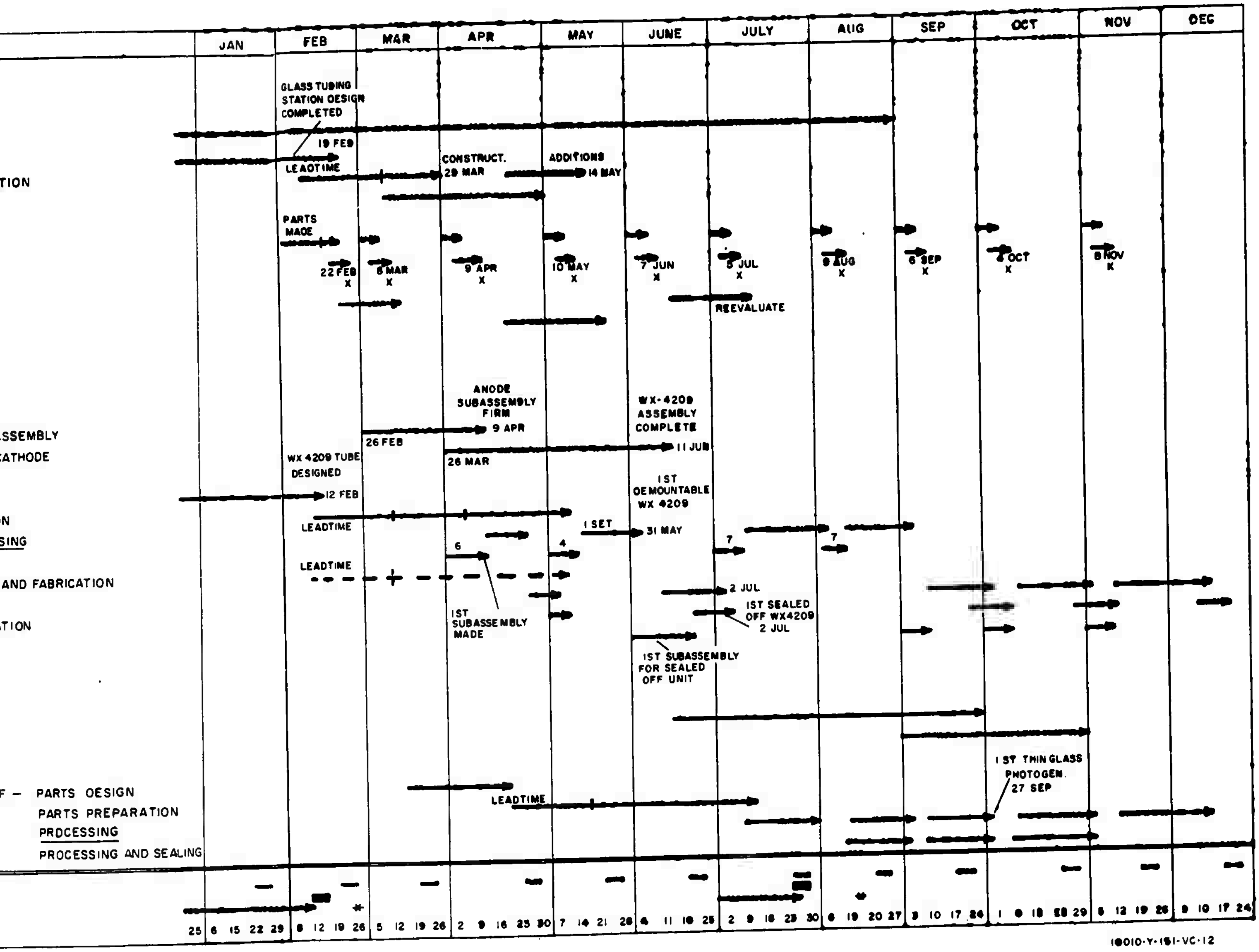


Figure 12. Schedule of Work

2

SECTION VII

IDENTIFICATION OF PERSONNEL

7.1 PERSONNEL ASSIGNED

IGOR LIMANSKY (2086 hrs., 28.5% of Total Effort to Date)

Education

University of Rochester, B.S. in Mechanical Engineering, 1945

New York University, M.S. in Electrical Engineering, 1953

University of Michigan, M.S. in Nuclear Engineering, 1957

Professional Experience

1947 - 1955	Amperex Electronic Corporation, Hicksville, Long Island, New York. Engineer. Designed a variety of test equipment to check hydrogen thyratrons, magnetrons, high-voltage rectifiers, and geiger tubes.
1955 - 1959	The Martin Company, Baltimore, Maryland. Senior Engineer. Circuit design engineering, pulse and wide-band VHF amplifier.
Since 1959	Electronic Tube Division of Westinghouse Electric Corp., Baltimore, Maryland. Senior Engineer. Development work on special electron devices.

Military Service

1943 - 1946	U.S.M.C.R. Participated in the occupation of North China.

Accomplishments

Two papers on hydrogen thyratron jitter given at the Third and Fourth Hydrogen Thyratron Symposium.

Affiliations

Member of the IRE

American Physical Society

ARTHUR S. JENSEN (546 hrs., 7.4% of Total Effort to Date)

Education

University of Pennsylvania, B.S., 1938

University of Pennsylvania, M.S. in Physics, 1939

University of Pennsylvania, Ph. D. in Physics, 1941

Professional Experience

1941	Naval Research Laboratory, Washington, D.C. Research Physicist. Research in radar circuits.
1945 - 1957	RCA Laboratories, Princeton New Jersey. Research Physicist. Research and invention in fields of storage tubes (The Radechon), switching and coding tubes, pulse amplitude analyzers, color television systems, bandwidth compression, panel displays, gas discharges, secondary emission of insulators.
Since 1957	Electronic Tube Division of Westinghouse Electric Corporation, Baltimore, Maryland. Section Manager. Direct research and invention in fields of storage tubes, switching and coding tubes, photoelectric devices, infrared detectors, and other special electron devices.

Military Service

1941 - 1945	U.S. Navy, Officer-Instructor in Physics, U.S. Naval Academy, Department of Electrical Engineering. Captain, USNR.

Accomplishments

Eight patents have been issued, four patents are pending, and ten Westinghouse disclosures are in process.

Fifteen articles in Phys Rev., RCA Rev, Amer. J. Phys, etc.

Affiliations

Senior Member of the IRE.

Editor of "The P.S.," Local Bulletin of the Princeton Section of the IRE, 1955 and 1956.

Member of the IRE sub-committee, 7.10, Storage Tubes.

Member of American Physical Society, American Association of Physics Teachers, AAAS, U. S. Naval Research Reserve, Pi Mu Epsilon, and Sigma Xi.

EDWIN F. WOOD (1791 hrs., 24.4% of Total Effort to Date)

Education

Rochester Institute of Technology, A.A.S. in Chemistry, 1954.

Rochester Institute of Technology, B.S. in Industrial Chemistry, 1956.

Professional Experience

1951 - 1953	Westinghouse Electronic Tube Division, Elmira, New York, Laboratory Technician in Applications Engineering.
1953 - 1956	Navy Ordnance Division, Eastman Kodak Company, Rochester, New York, Technician in Metal Plating, Metallurgical, Analytical, Plastic, and Quality Control Laboratories.
1956 - 1958	RCA Electron Tube Division, Harrison, New Jersey. Associate Engineer. Chemical and Physical Laboratory. Development work on vacuum tube materials and processing.
1958 - 1959	Nicolet Industries, Florham Park, New Jersey. Chemist. Research and analytical development work on asbestos products and fiberglass-plastic laminates.
1959	Electronic Tube Division of Westinghouse Electric Corporation, Baltimore, Maryland. Associate Engineer. Working on development of special electron devices.

Military Service

1944 - 1946	U.S. Army. Heavy weapons infantry, radio school and military police.

Accomplishments

RCA Technical Report, "The Effect and Remedies of Parasitic Oscillations during the Aging and Life-testing of Tubes."

Patent disclosure related to above concerning a device for internal suppresion of parasitic oscillations.

Affiliations

Associate Member, Institute of Radio Engineers.

Student Affiliate of American Chemical Society.

Member of American Radio Relay League.

7.2 **OTHER ENGINEERING ASSISTANCE**

(641 hrs., 8.7% of Total Effort to Date)

7.3 **TECHNICIAN SUPPORT**

(2277 hrs., 3.10% of Total Effort to Date)

7.4 **ERRATA**

The figures given above, represent a corrected estimate of the total effort since the beginning of the contract 8 September 1959. The Second Semiannual Report figures given in Section VII are in error, since the total effort during the period 8 September 1959 through 31 December 1959 was not included. The Second Semiannual Report must therefore be corrected to read after each accounting: (".... of Total Effort this period) instead of (".... Total Effort to date).

APPENDIX A

TUBE PROCESSING DATA

The following tables show on-the-pump processing information on representative tubes.

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesium) (amperes)
Bake	400°C	60 minutes			
Leak check	Room				
Getter outgas	Room				
Ag-Bi outgas and	Room	1 minute	1.0		
Evaporation	Room	1 minute	1.5		
	Room	1 minute	1.75		
			2.0		
Oxidation	Room	1 minute			
Cesiation	150°C				4.5
	150°C	1 minute			5.0
	150°C	1 minute			5.4
	150°C	2.5 minutes			6.2
					6.2
					0
					6.2
					0

1

TABLE A-1

TUBE NO. WX-3964-2

I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
					Manifold valve open
		2.4×10^{-6}			
					Not done
	4-7				
	4-7				
	4-7				
	4-7				50 percent transmission
		0.150			Glow discharge
4.5	3-6				Until outgassing completed
5.0	3-6				
5.4	3-6	8×10^{-6}	6		Valve open
6.2	3-6	8×10^{-6}	18		Valve open
6.2	3-6		12		Valve open
0	3-6	8×10^{-6}	4		Valve open
6.2	3-6	8×10^{-6}	12		Valve closed
0	3-6	8×10^{-6}	4		Valve closed

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesiu (ampere
Bake	400°C	60 minutes			
Leak check	Room				
Getter outgas	Room	5 minutes		4.0	
Ag-Bi outgas and evaporation	Room	1 minute	1.0		
	Room	1 minute	1.5		
	Room	1 minute	1.75		
			2.0		
Oxidation	Room	1 minute			
Cesiation	150°C				0
	150°C				5
	150°C				5.5
	150°C				6.0
	150°C				6.4

1

TABLE A-2

TUBE NO. WX-3964-3

I (...tter) (...peres)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
)						Spark faceplate with high voltage
		4-7				
		4-7				
		4-7				
		4-7				38 percent transmission
			0.150			66 percent transmission (glow discharge)
	0	3-6	1×10^{-6}	0		Valve open
	5	3-6	1×10^{-6}	16		Valve open
	5.5	3-6	1×10^{-6}	13		Valve closed
	6.0	3-6	1×10^{-6}	6		Valve closed
	6.4	3-6	1×10^{-6}	12		Valve closed

2

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesium) (amperes)
On exhaust (Bake)	250°C	09:40			
	300°C	10:05			
	400°C	10:35			
	Room	10 second			
Ag-Bi outgas and evaporation	Room	13:15 +			
	Room	30 seconds	1.0		
	Room	30 seconds	1.5		
	Room	30 seconds	1.7		
	Room	30 seconds	2.0		
	Room	30 seconds	2.1		
	Room	30 seconds	2.2		
	Room	30 seconds	2.3		
Oxidation	Room	1 minute			
Cesiation	165°				0
	165°	15 minutes			3.8
	165°				0
	165°	1 minute			5.0
	165°	1 minute			5.4
	165°	2 minutes			5.8

1

TABLE A-3

TUBE NO. WX-3964-E-4

r) es)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
			7×10^{-5}			
			8×10^{-5}			
			2×10^{-5}			
			0.10			Glow discharge faceplate with O_2
		4-7				
						5 percent transmission
			0.150			5 percent transmission
	0	3-6				4 microamps leakage current
	3.8	3-6	6×10^{-5}			Outgas
	0	3-6				0.1 microamps leakage current
	5.0	3-6		1.0		
	5.4	3-6		3.5		
	5.8	3-6		10		

2

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (ces (amp
Bake	400 °C	1 hour			
Getter outgas	Room	5 minutes		4.0	
Spark	Room	30 seconds			
Ag-Bi outgas and evaporation	Room	1 minute	1.0		
	Room	1 minute	1.5		
	Room	1 minute	1.75		
	Room	30 seconds	2.0		
	Room	1.5 minutes	2.3		
Oxidation	Room	1 minute			
Cesiation	150°C	15 minutes			3.8
	150°C	1 minute			5.0
	150°C	1 minute			5.4
	150°C	15:20			0
	150°C	15:36			6.8
	150°C	15:40			6.8
	150°C	15:41			6.9
	150°C	15:42			6.9
	150°C	15:43			6.6
	150°C	15:45			6.8
	150°C	15:47			6.9
	150°C	15:50			7.0
	150°C	16:51			6.8
	150°C	17:05			0
	Room	17:08			0

1

TABLE A-4

TUBE NO. WX-3964-E-5

I etter) nperes)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
4.0						
						High voltage on faceplate
		4-7				
		4-7				
		4-7				
		4-7				50 percent transmission
		4-7	1×10^{-6}			3 percent transmission
			(0.150)			5 percent transmission
	3.8	3-6				100-watt lamp at 2 feet
	5.0	3-6				Anode volts +20
	5.4	3-6				
	0	3-6		0		
	6.8	3-6		0.12		
	6.8	3-6		0.60		
	6.9	3-6		0.80		
	6.9	3-6		0.92		
	6.6	3-6		1.20		
	6.8	3-6		1.30		
	6.9	3-6		1.60		
	7.0	3-6		3.00		
	6.8	3-6		3.00		
	0	3-6		2.80		
	0	3-6		2.70		

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesiu (amper
Bake	400°C	1 hour			
Getter outgas	Room	09:25		2.0	
Spark faceplate	Room	09:30			
Ag-Bi outgas and evaporation	Room	1 minute	1.0		
	Room	1 minute	1.5		
	Room	1 minute	1.75		
	Room	09:37			
Oxidation	Room	1 minute			
Cesiation	150°C	15 minutes			3.8
	150°C	1 minute			5.0
	150°C	1 minute			5.4
	150°C	10:35			6.4
	150°C	10:45			6.5
	150°C	10:46			6.5
	150°C	10:48			6.5
	150°C	10:50			6.5
	150°C	10:54			6.5
	150°C	10:57			6.5
	150°C	10:58			6.5
	150°C	10:59			5.5
	150°C	11:02			0.0
	Room	11:05			0.0
	Room	11:09			0.0
Flash getter	Room	30 seconds		5.0	
	Room	11:13			0.0

1

TABLE A-5

TUBE NO. WX-3964-E-6

I getter) nperes)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
2.0						
		4-7				
		4-7				
		4-7				
		4-7	2.5×10^{-6}		30	
			(0.150)		34	No glow discharge
	3.8	3-6				100-watt lamp at 2 feet
	5.0	3-6				Anode volts +20
	5.4	3-6				
	6.4	3-6		3.5		
	6.5	3-6		5.5		
	6.5	3-6		10.0		
	6.5	3-6		10.5		
	6.5	3-6		12.5		
	6.5	3-6		11.5		
	6.5	3-6		8.5		
	6.5	3-6		9.2		
	5.5	3-6				Drop heater current to 1 amp per minute
	0.0	3-6		13.0		Drop heater current to zero
	0.0	3-6		15.0		Over raised (leakage)
	0.0	3-6		17.0		
5.0						
	0.0			5.0		

2

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesium) (amperes)
Evacuate	Room	13:30			
Bake	200°C	13:50			
	300°C	14:10			
	400°C	14:45			
	400°C	15:00			
	Room	16:45			
	Room	08:00			
	200°C	08:20			
	200°C	08:35			
	Room	09:00			
Getter outgas	Room	09:15		7.0	
Ag-Bi outgas and evaporation	Room	30 seconds	1.0		
	Room	30 seconds	1.5		
	Room	30 seconds	1.75		
	Room	30 seconds	2.0		
	Room	30 seconds	2.1		
	Room	40 seconds	2.2		
Spark faceplate	Room	09:30			
Oxidation	Room	09:35			
Ceisation	150°C	13:30			2
	150°C	13:33			3
		13:34			4
		13:36			4.5
		13:39			5
		13:41			5.2
		13:43			5.5
		13:44			5.8

1

TABLE A-6

TUBE NO. WX-3964-E-7

I (getter) (amperes)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
			5×10^{-5}			
			3×10^{-5}			
			2×10^{-5}			
			1×10^{-5}			Turn off oven
			5×10^{-6}			
			1×10^{-5}			
			1×10^{-5}			
			1.7×10^{-5}			Turn off oven
7.0			7×10^{-6}			5 minutes degas
		4-7				
			9×10^{-6}			
					30 percent	
		3-6			36 percent	Glow discharge
	2			0		
	3			0		
	4			0		
	4.5			0		
	5		3×10^{-6}	0		
	5.2		3×10^{-6}	0		
	5.5		3×10^{-6}	0		
	5.8			0		

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesium) (amperes)
Cesiation	150°C	13:46			
	150°C	13:48			5.4
	150°C	13:52			5.8
	150°C	13:55			5.8
	150°C	13:56			6.0
	150°C	14:00			5.4
	150°C	14:07			6.0
	150°C	14:20			6.0
	150°C	14:26			6.0
	150°C	14:31			6.0
	150°C	14:32			5.0
	150°C	14:33			4.0
	150°C	14:34			3.0
	150°C	14:35			2.0
	150°C	14:36			1.0
	150°C	14:37			0
	150°C	14:45			
	150°C	14:46			6.8
	150°C	14:50			6.0
	150°C	15:00			0
	Room				

TABLE A-6 (Continued)

...er) ...eres)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
		3-6				Outgas
	5.4	3-6		0.5		
	5.8	3-6		0.5		
	5.8	3-6		1.5		
	6.0	3-6		1.5		
	5.4	3-6		1.75		
	6.0	3-6		3.0		
	6.0	3-6	6×10^{-6}	7.5		
	6.0	3-6		7.0		
	6.0	3-6		6.0		
	5.0	3-6		5.0		
	4.0	3-6		4.0		
	3.0	3-6		3.0		
	2.0	3-6		2.0		
	1.0	3-6		2.0		
	0	3-6		2.0		
						Reduce cesium current to 7 amp per minute
	6.8			3.0		
	6.0			3.0		
	0			1.5		Raise oven
			2.5×10^{-6}	1.5		Tip-off

2

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesium) (amperes)
Bake	25°C	08:15			
	200°C	08:30			
	300°C	08:45			
	400°C	09:15			
Getter outgas	Room	10:45		2	
Spark faceplate	Room	10:50			
Ag-Bi outgas and evaporation	Room	30 seconds	1.0		
	Room	30 seconds	1.5		
	Room	30 seconds	1.75		
	Room	30 seconds	2.0		
	Room	30 seconds	2.1		
	Room	1 minute	2.2		
	Room	20 seconds	2.3		
Oxidation	Room	1 minute			
Cesiation	150°C	12:00			2.0
	150°C	12:02			3
		12:05			4
		12:07			5
		12:12			5.5
		12:20			5.8
		12:25			6.0
		12:30			6.0
		12:40			6.0
		13:00			
		14:00			

1

. TABLE A-7

TUBE NO. WX-3964-E-8

r) es)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
			1×10^{-5}			
			2×10^{-5}			
			1×10^{-5}			
			1×10^{-5}			
			5×10^{-6}			5 minutes outgas
		4-7				
		4-7				
		4-7				
		4-7				
		4-7				
		4-7				
		4-7			30	
						Glow discharge
	2.0	3-6		0		
	3	3-6		0		
	4	3-6	7×10^{-6}	0		
	5	3-6		0		
	5.5	3-6	2.5×10^{-6}	0		
	5.8	3-6		15		
	6.0	3-6		1.0		
	6.0	3-6		14		
	6.0	3-6		22		
						Tip-off (intermittent internal short)
			2.0×10^{-6}	5		

2

OPERATION	TEMPERATURE	TIME	I (Ag-Bi) (amperes)	I (getter) (amperes)	I (cesium) (amperes)
Bake	400°C	7 hours			
	150°C	15:02			
Getter outgas	Room	5 minutes		2.0	
Ag-Bi outgas and evaporation	Room	30 seconds	1.0		
	Room	30 seconds	1.5		
	Room	30 seconds	1.75		
	Room	30 seconds	2.0		
	Room	30 seconds	2.1		
	Room	30 seconds	2.2		
	Room	2 minutes	2.3		
Oxidation	Room				
Cesiation	150°C				6
	150°C				5
	150°C				6
	150°C				4
	150°C				3
	150°C				2
	150°C				0
Reactivation	150°C				6
	150°C				6.5
	150°C				5.5
	150°C				4
	150°C				3
	150°C				2

1

TABLE A-8

TUBE NO. WX-3964-E-9

I getter) nperes)	I (cesium) (amperes)	IMAGE LEADS	PRESSURE (mm Hg)	I_{PE} (microamps)	PERCENT TRANSMISSION	REMARKS
2.0						
		4-7				
			3×10^{-6}		30	
			0.150		30	No change in transmission
	6	3-6		100/60		
	5			30		Note: The second reading signifies dark current.
	6			65/35		
	4			10		
	3			8		
	2			0		
	0			5/2		
	6			52		
	6.5			140		
	5.5			31		
	4			9		
	3			8		
	2			6		

APPENDIX B

CALCULATIONS FOR PHOTOCELL TESTING STATION

Photocell test lamps are calibrated in candles in a specified direction by the National Bureau of Standards. The geometry necessary to give a solid angle subtending a light flux of L lumens is calculated below.

By definition, 4π lumens per candle are emitted through the surface of any sphere of radius R. To restrict the light flux for the purpose of measurement of photoemissive surfaces, an iris is placed at a distance R from the light source of candle power I as shown in figure B-1.

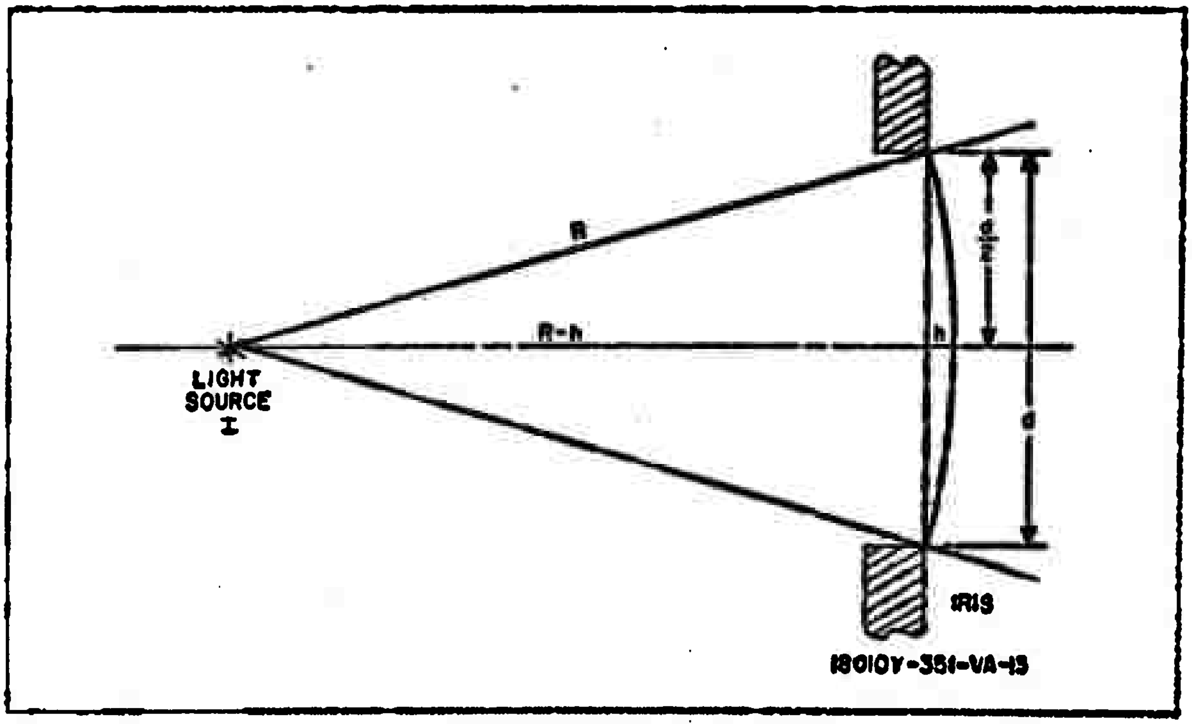


Figure B-1. Photocell Testing Station Geometry

Of the total flux of $4\pi I$ lumens passing through a sphere of radius R, only that portion passing through the cap is desired, i.e., L lumens. This is computed by

$$L = (\text{total light flux}) \times \frac{\text{area of cap}}{\text{surface area of sphere}}$$

$$L = 4\pi I \left(\frac{2\pi Rh}{4\pi R^2} \right) \quad \text{where: } h = R \pm \sqrt{R^2 - \frac{d^2}{4}} \quad \text{(From figure B-1)}$$

Therefore, solving for R in terms of the other variables,

$$R = \frac{\pi d \left(\frac{I}{L} \right)}{\sqrt{4\pi \left(\frac{I}{L} \right) - 1}}$$

For a Westinghouse Test Lamp 5A/T14P, NBS Designation 6053

I = 115.6 candle power

L = 1 lumen desired

d = 1-inch circular aperture

$$R = \frac{\pi (1) \left(\frac{115.6}{1} \right)}{\sqrt{4\pi \left(\frac{115.6}{1} \right) - 1}} = 9.53 \text{ inches}$$

This can be taken as the distance (R - h), since h is less than 0.05 inch. Also, by similar triangles, the distance between a 3-inch photocathode and the light source is 3 times the distance between iris and light source, or 28-1/2 inches.

The following parameters have been calculated for the NBS 6053 photocell test light:

Lumens	Iris d (inches)	Distance R (inches)
0.1	0.5	15.1
0.1	1.0	30.1
1.0	1.0	9.5
10.0	1.0	3.0

APPENDIX C

TENTATIVE DESIGN OF WX-4209

The following figures depict the tentative design of Tube WX-4209.

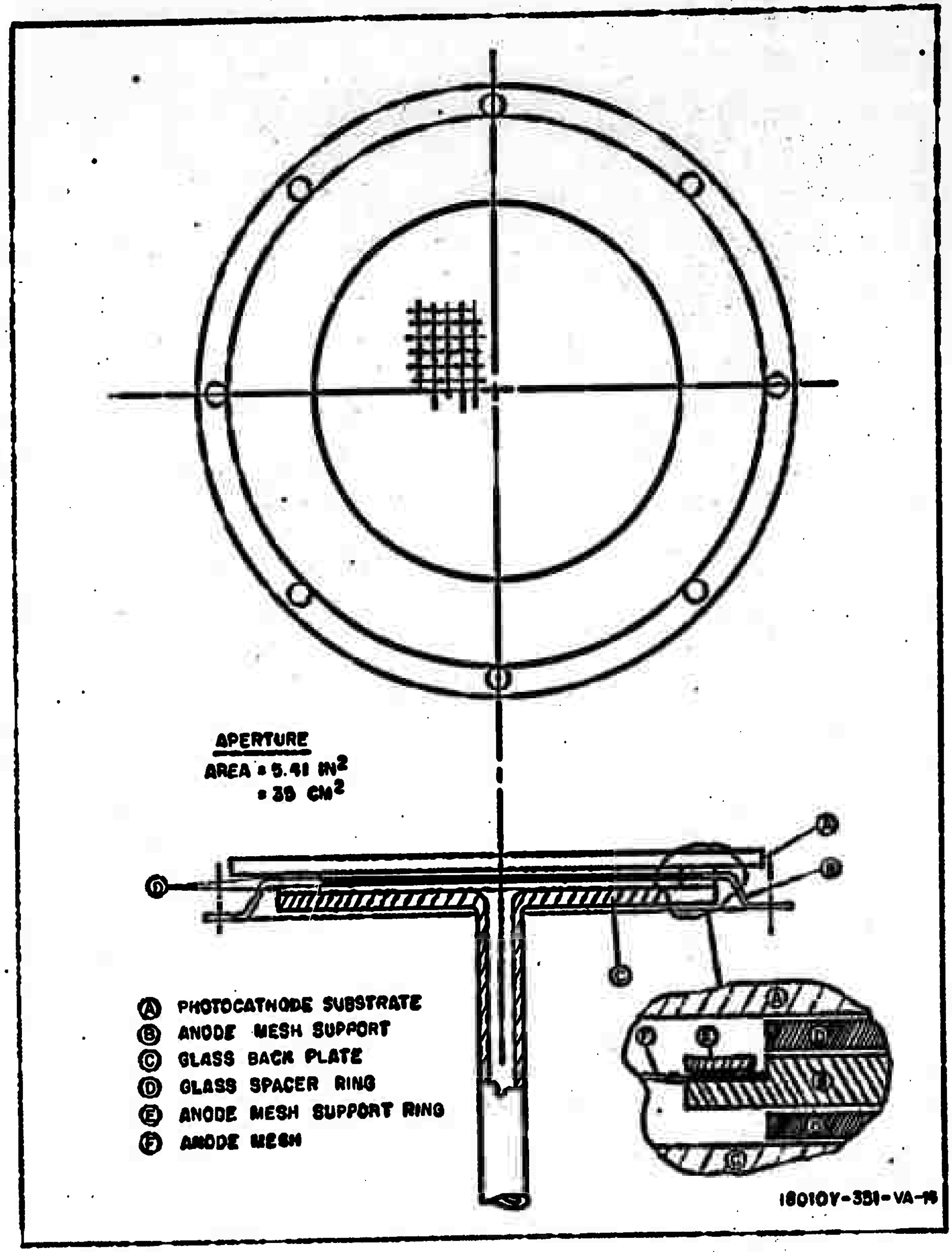


Figure C-1. WX-4209 Photoemissive Power Converter Assembly

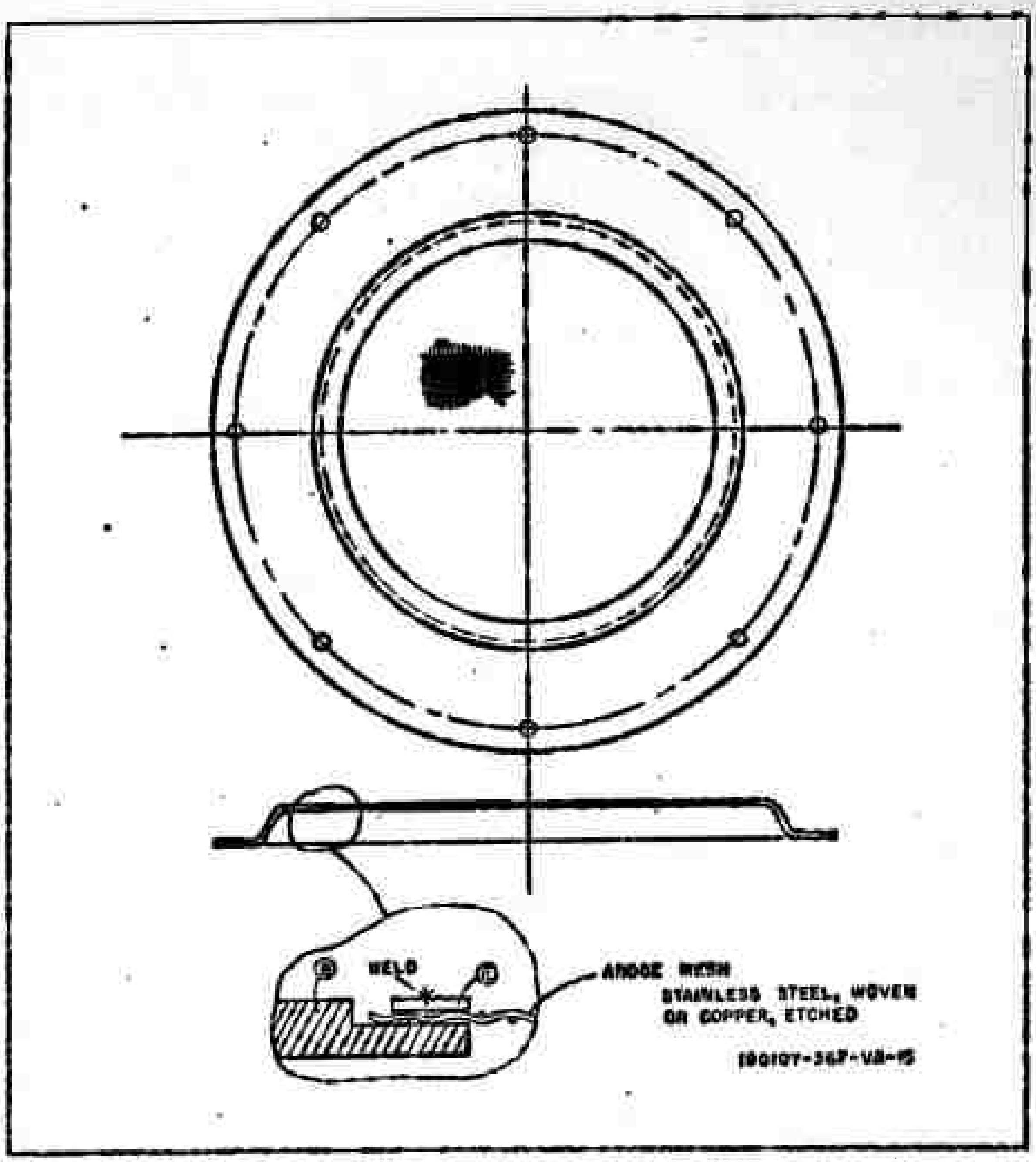


Figure C-2. WX-4209 Photoemissive Power Converter - Mesh to Anode Support Assembly

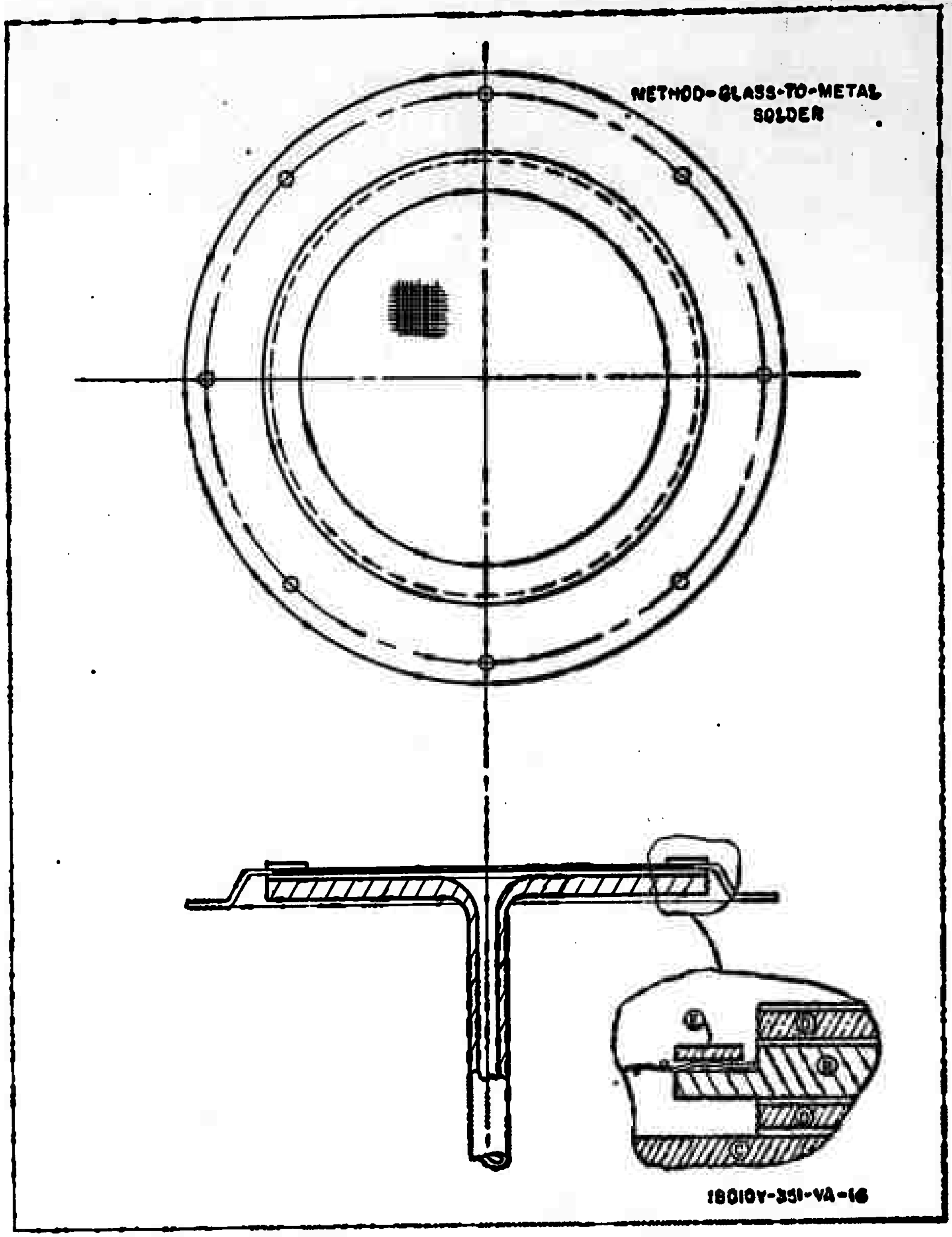


Figure C-3. WX-4209 Photoemissive Power Converter
Anode Subassembly

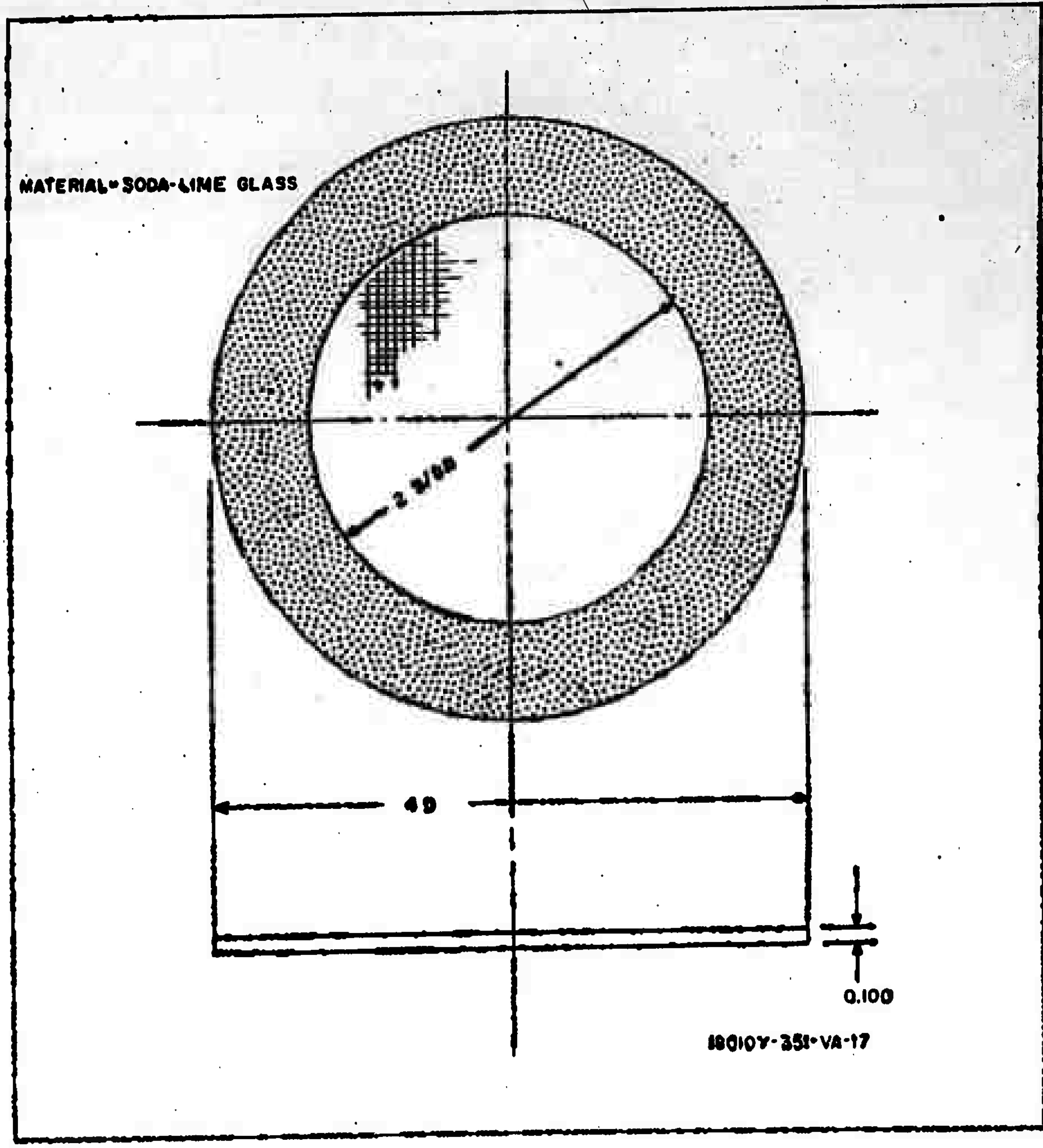


Figure C-4. WX-4209 Photoemissive Power Generator
(A) Photocathode Substrate

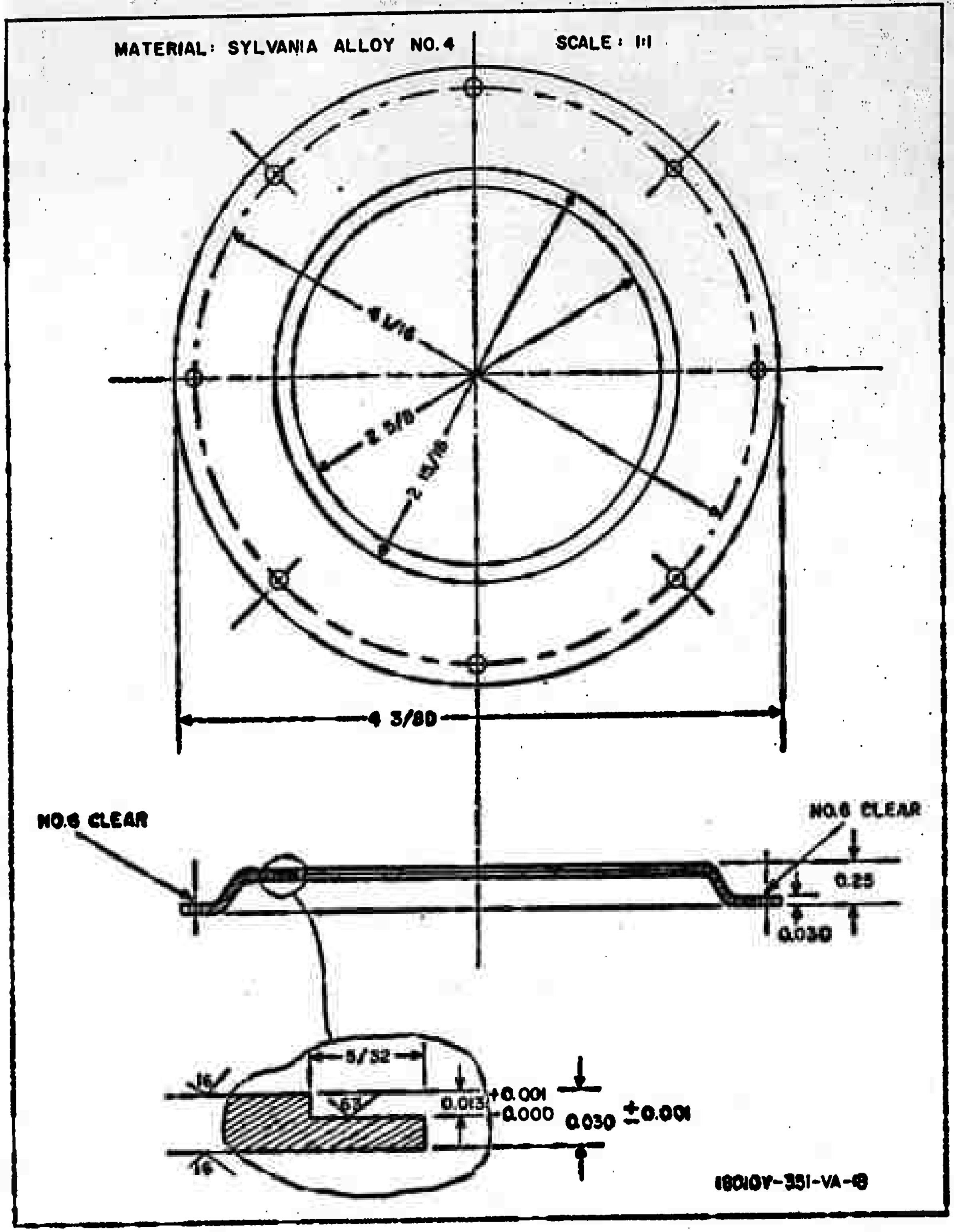


Figure C-5. WX-4209 Anode Mesh Support

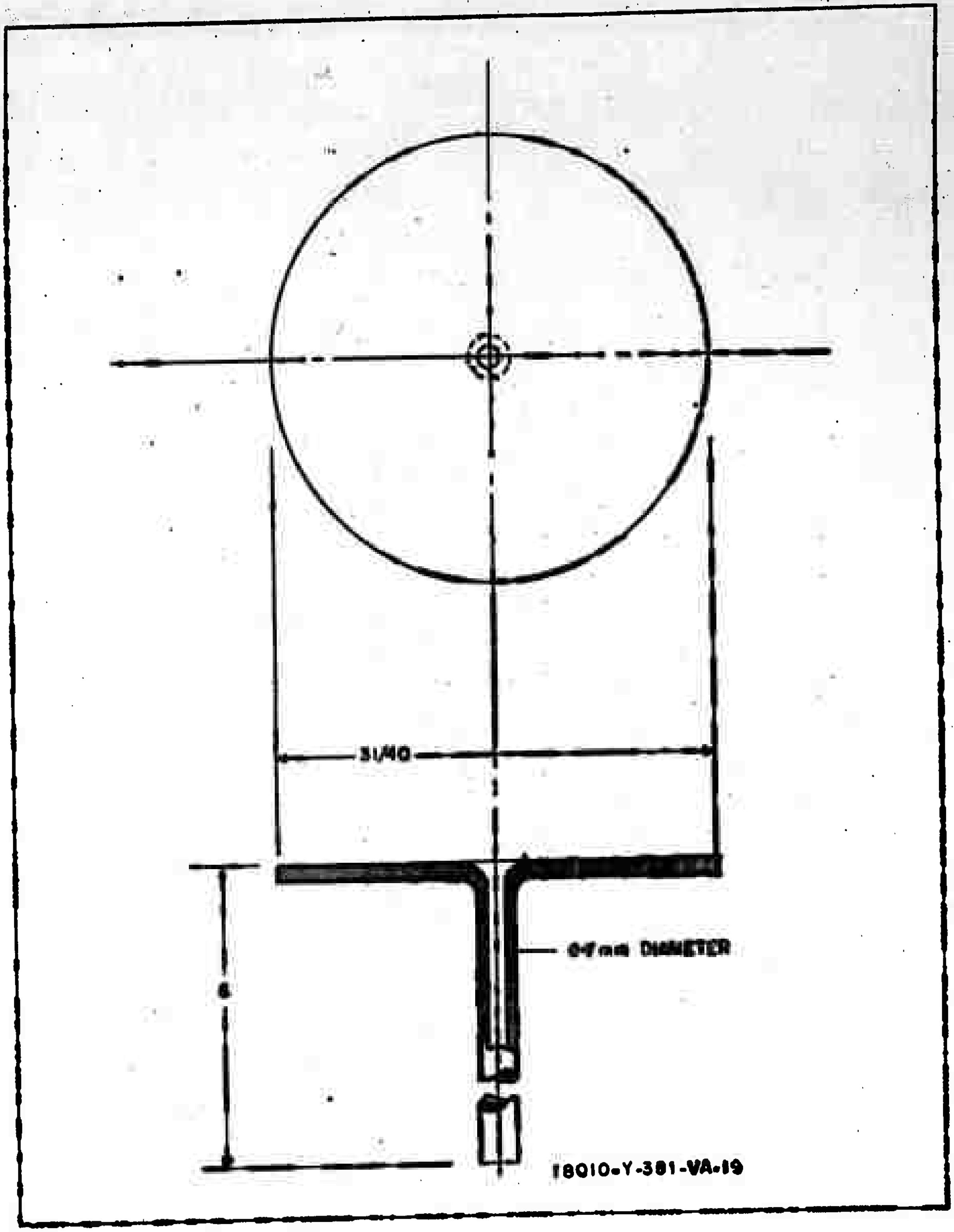


Figure C-6. WX-4209 Photoemissive Power Generator
© Glass Back Plate

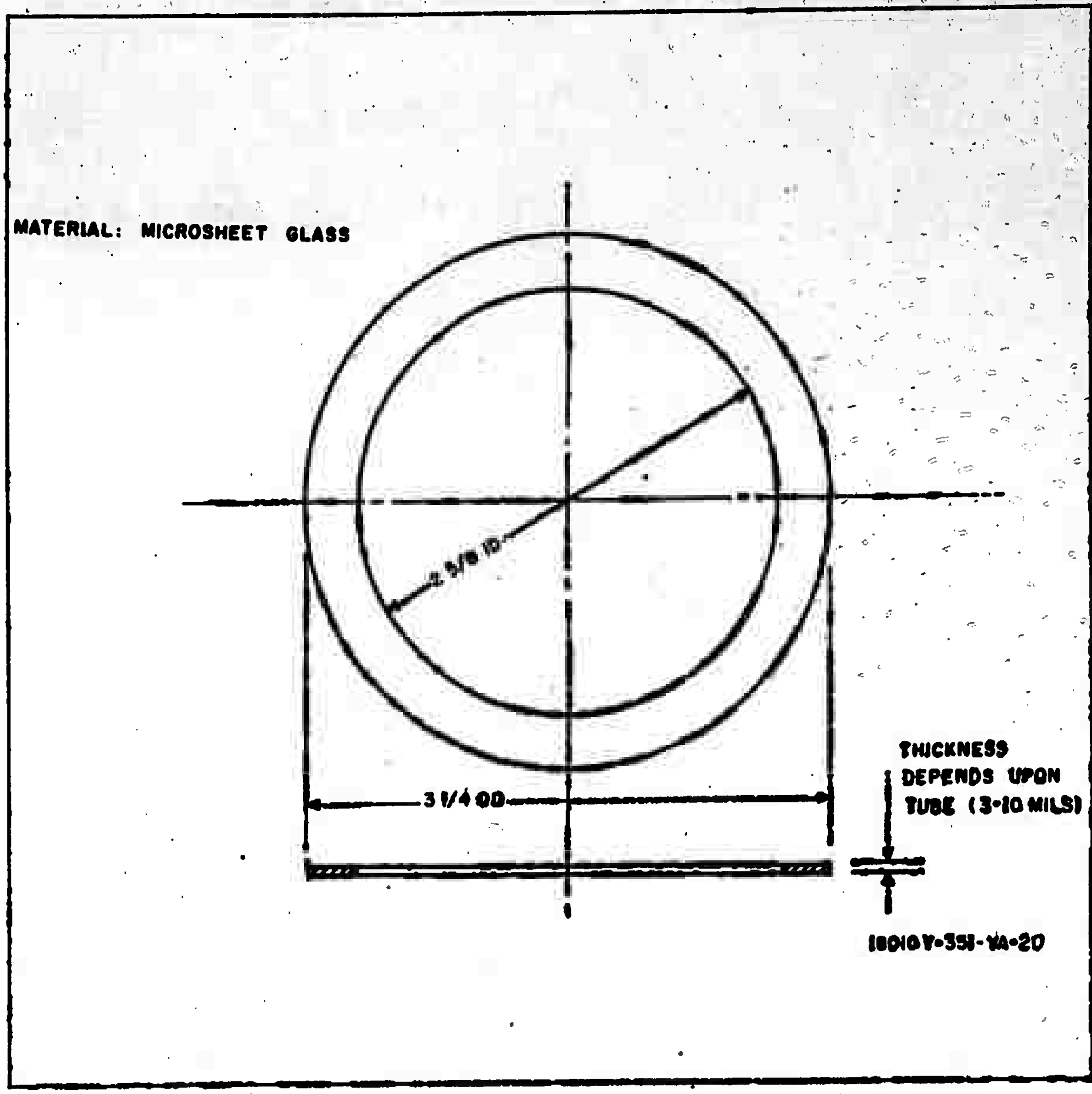


Figure C-7. WX-4209 Glass Spacer Ring (D)

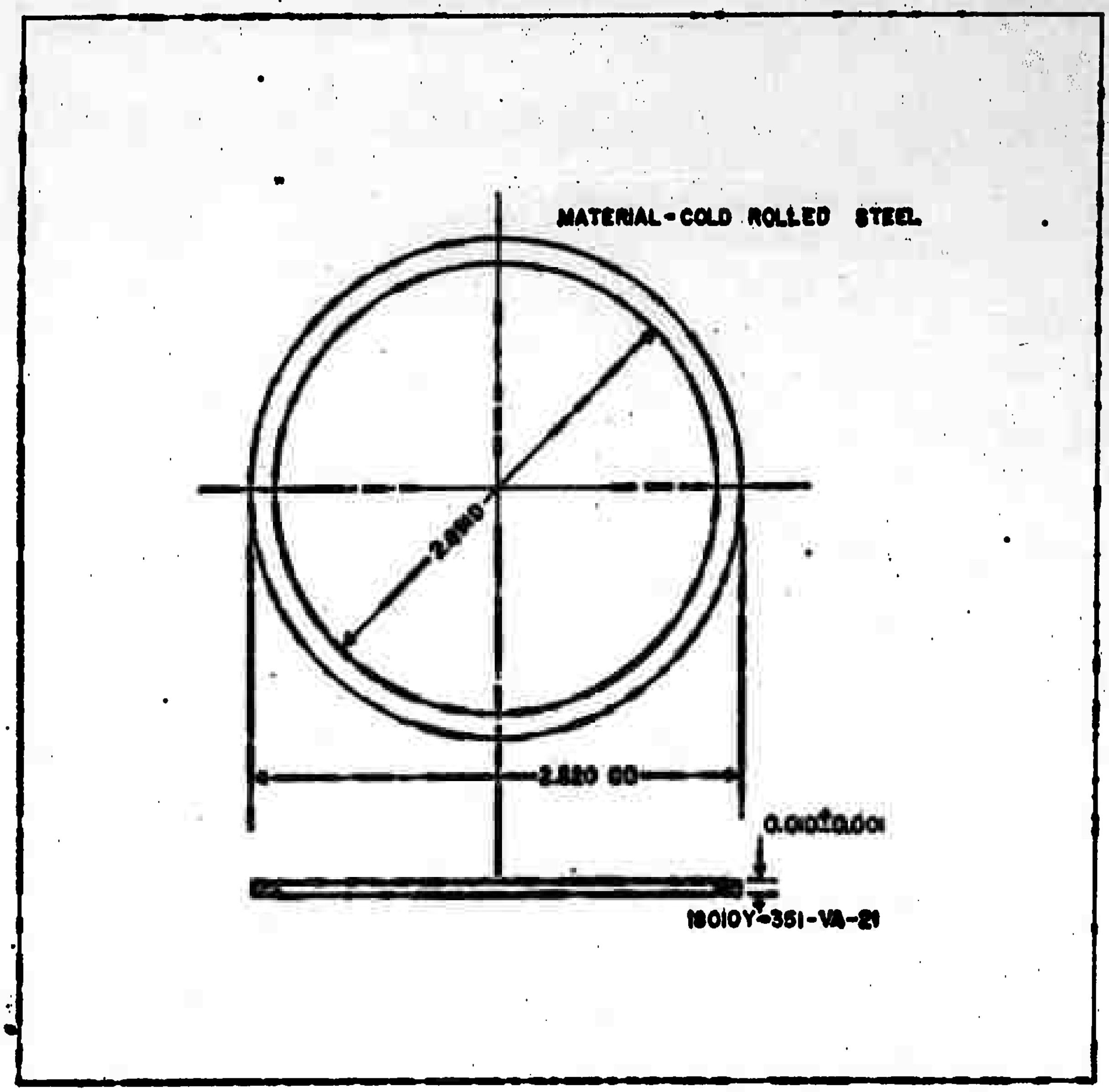


Figure C-8. WX-4209 Anode Mesh Support Ring (E)

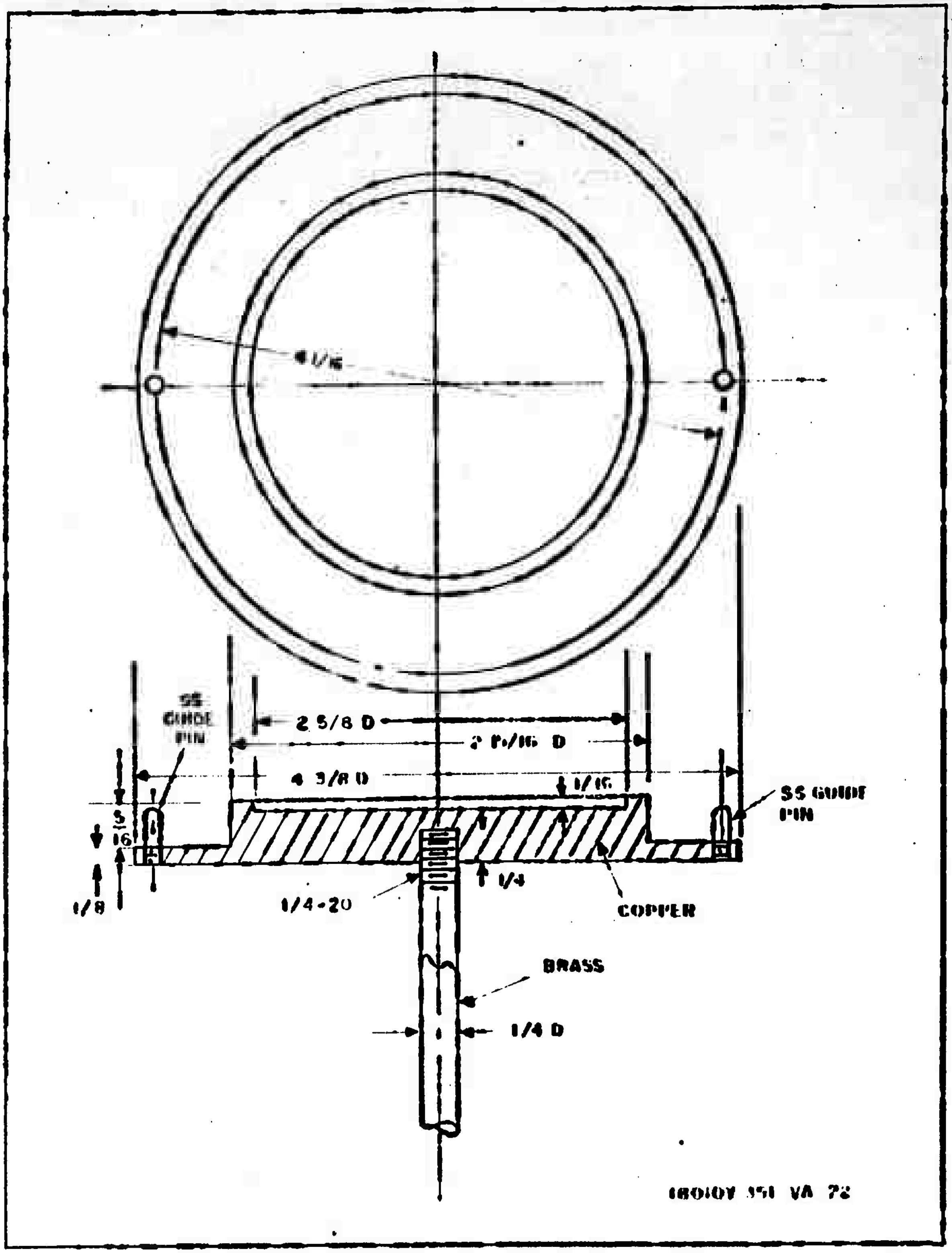


Figure C-9. WX-4209 Photoemissive Power Generator - Welding Jig - Anode Mesh to Anode Support

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